The Engineer

NOVEMBER 27, 1953 28 ESSEX ST., STRAND, LONDON, W.C.2. TWO SHILLINGS

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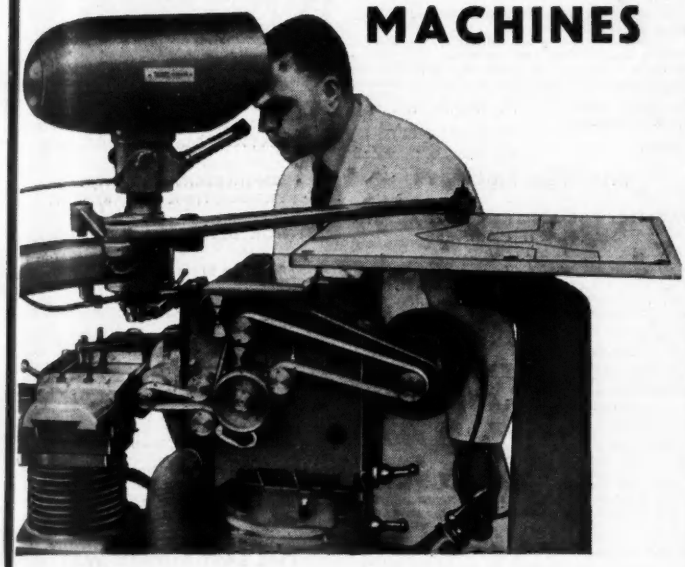

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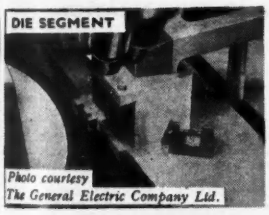

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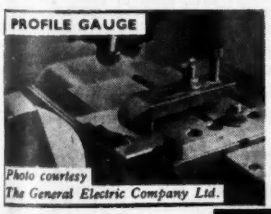

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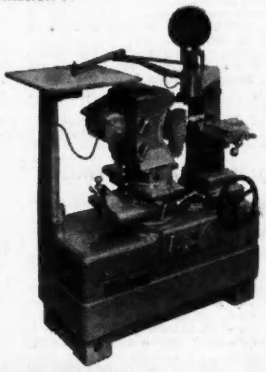
These machines are currently used in the toolrooms of a host of important aircraft, automobile, watchmaking and general engineering organisations for the production of profile gauges, form tools, press tools and many other highly precise aids to production. We would like you to meet some of the users —"The most helpful piece of equipment we've got," says one: and another, "We could not produce our type of work without it." Why not let us take you round, or send you fuller information ?



Wickman

WICKMAN *of* COVENTRY

327 WMG

THE ENGINEER

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NOVEMBER 27, 1953

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NOTICE TO READERS
All letters intended for insertion in 'The Engineer' or containing questions should be accompanied by the name and address of the writer, not necessarily for publication, but as a proof of good faith. No notice whatever can be taken of anonymous communications. No undertaking can be given to return drawings or manuscripts; correspondents are therefore requested to keep copies.

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Advertisements received by Mid-day Tuesday will appear in the issue of Friday the same week. Orders must be accompanied by a remittance.

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PUBLIC APPOINTMENTS

UNIVERSITY OF CAPE TOWN
SOUTH AFRICA

LECTURESHIP IN CIVIL ENGINEERING

Applications are invited for a LECTURESHIP IN CIVIL ENGINEERING. Experience in the construction of dams, irrigation works, heavy foundations, highways or bituminous material research or the application in practice of the principles of soil mechanics, would be a recommendation.

The salary scale is £650 by £50 to £1000 per annum, plus a temporary cost-of-living allowance (at present £320 per annum for a married man and £100 per annum for others). The standard salary scale recognised for the provident fund is £650 by £50 to £900.

Applications (with copies of testimonials) should state age, experience, qualifications and research work completed or in progress, and give the names of two referees whom the University may consult. Two copies of the application and testimonials should reach the Secretary, Association of Universities of the British Commonwealth, 5, Gordon Square, London, W.C.1 (from whom a memorandum giving the general conditions of appointment should be obtained), not later than 25th January, 1954. An additional copy should be sent direct by air mail to the Registrar, University of Cape Town, Private Bag, Rondebosch, Cape Town, South Africa, by the same date.

The University reserves the right to appoint a person other than one of the applicants or to make no appointment. E6232

UNIVERSITY OF SHEFFIELD

MAINTENANCE ENGINEER

Applications are invited from suitably qualified persons for the post of MAINTENANCE ENGINEER. Duties comprise maintenance of University buildings, heating, lighting and other services, control of porters, boilermen, cleaners and other maintenance staff. Initial salary £800–£900, according to qualifications and experience, with superannuation benefits and family allowance. A period of probation may be required.

Further particulars can be obtained from the Bursar, The University, Sheffield, 10, to whom applications (giving the names of two referees) should be sent by 5th December, 1953. E6178

WIGAN AND DISTRICT MINING AND TECHNICAL COLLEGE

LECTURER IN ELECTRICAL ENGINEERING

The Governing Body invites applications for a post as LECTURER IN ELECTRICAL ENGINEERING. Duties will commence as soon as possible.

Candidates should hold a Degree in Electrical Engineering and should be able to teach up to Final Degree standard. Salary in accordance with the Burnham Technical Scale for Lecturers (£940–£25–£1040).

Further particulars and application form will be sent by the undersigned on receipt of a stamped, addressed, foolscap envelope. Last date for receipt of applications Monday, 14th December, 1953. Applications not on the form provided will be disregarded.

E. C. SMITH,
Principal.

20th November, 1953. E6221

NORTHAMPTONSHIRE EDUCATION COMMITTEE

WELLINGBOROUGH TECHNICAL COLLEGE

(Principal: S. A. J. PARSONS, B.Sc. (Econ.), M.I.Mech.E.)

ASSISTANT MASTER

Required, as soon as possible, an ASSISTANT MASTER to teach general engineering subjects, with a special interest in engineering drawing, mainly for Final City and Guilds work. Teaching and industrial experience is desirable.

Salary in accordance with Grade A of the Burnham Scale of Salaries for Teachers.

Forms of application and particulars may be obtained from the undersigned, to whom completed applications should be returned by 12th December, 1953.

Candidates desiring the return of their testimonials should forward a stamped, addressed envelope.

G. E. CHURCHILL,
Chief Education Officer.

County Education Offices,
Northampton,
November, 1953. E6247

MINISTRY OF SUPPLY

EXPERIMENTAL ESTABLISHMENT

PHYSICISTS AND ENGINEERS

PHYSICISTS and ENGINEERS, with good practical ability and interest in development work, required by Ministry of Supply Experimental Establishment near Salisbury, Wilts. Scientific Officers, 1st or 2nd Class Honours Degree or equivalent in Physics or Engineering required; knowledge of explosives desirable. Experimental Officers and Assistant E.O.s., minimum of Higher School Cert. (Science) or equivalent, required, but Degree or H.N.C. may be an advantage. Two posts comprise field trials work and planning, recording, collating results. Salaries within ranges: S.O., £417–£781 (F.S.S.U. benefits may be available); E.O. (min. age 26), £649–£799; A.E.O., £264 (age 18)-£576. Women somewhat less. Appointments unestablished. —Application forms from M.L.N.S., Technical and Scientific Register (K), 26, King Street, London, W.1, quoting A293/53/A. E6205

PUBLIC APPOINTMENTS

HER MAJESTY'S COLONIAL SERVICE

PUBLIC WORKS DEPARTMENT, NIGERIA

MECHANICAL ENGINEER (AIR CONDITIONING)

Duties include the selection, installation, control and maintenance of air conditioning and refrigerating plant in public offices and laboratories, collaboration with the engineering and architectural branches in the preparation of plans for air-conditioning schemes and assessment of the effectiveness of such installations in operation. The appointment is either pensionable on probation in the salary range £830 by £40 to £1560 per annum, or on contract in the range £895 by £44 to £1719 per annum, plus a gratuity of £100–£150 per annum on satisfactory completion of contract. Free first-class passages for the officer, his wife and an annual maintenance allowance or free passage allowance of up to £75 each is payable in respect of maximum of two children. Furnished quarters provided, if available, at low rental. Leave is granted at the rate of 7 days for each completed month of resident service in tour of 18–24 months.

Candidates should have passed or be exempt from Parts A and B of the examination for A.M.I.Mech.E. or A.M.I.C.E. (in a mechanical subject), or have a University Degree in Mechanical Engineering recognised by the Institution of Mechanical Engineers. They should have passed the Diploma Course or the Associateship Course of the National College for Heating and Ventilating Engineering and have had at least two years' post-graduate experience, or three years if qualifications were obtained without college course, in refrigeration, heating and ventilation.

Apply in writing to the Director of Recruitment, Colonial Office, Great Smith Street, London, S.W.1, giving briefly age, qualifications and experience. Mention the reference number CDE 112/14/018. E6238

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

NATIONAL PHYSICAL LABORATORY

PRINCIPAL SCIENTIFIC OFFICERS

Department of Scientific and Industrial Research require TWO PRINCIPAL SCIENTIFIC OFFICERS (unestablished) at the National Physical Laboratory, Teddington, for scientific information services. The duties involve liaison with industry, with particular emphasis upon ways and means whereby more rapid and effective use can be made by industry of the results of the Laboratory's work in physics, engineering and measurement techniques. Post (1) mechanical or electrical engineer, preferably with knowledge of metallurgy (Ref. C606/53A). Post (2) physicist, preferably with industrial experience (Ref. A298/53A). First or Second-Class Honours Degree or equivalent professional qualifications essential in both cases. The appointments are for three years only. Minimum age 31. Inclusive annual remuneration (45½-hour week) in the range £1171-£1550 (men), rather less for women.—Application forms from M.L.N.S., Technical and Scientific Register (K), 26, King Street, London, S.W.1, quoting appropriate reference. E6207

RHODESIA RAILWAYS

VACANCIES FOR CIVIL ENGINEERS

Vacancies exist for fully qualified CIVIL ENGINEERS for service in the Chief Engineer's Department of the Rhodesia Railways. Preferably applicants should be single men under the age of 25 years, but married men not exceeding 30 years of age may apply.

A Degree in Civil Engineering and/or Corporate Membership of the Institution of Civil Engineers is essential.

The grades of Junior and Assistant Engineer have salary scales between the limit of £560 and £1460 per annum, with incremental notches of £40 per annum, but the commencing salary would be determined in accordance with age and experience.

The vacancies are for appointment to the temporary staff in the first instance, but transfer to the permanent staff may be made either to fill vacancies or on the recommendation of the chief engineer.

Vacancies may occur later on for members of the permanent staff for the grade of District Engineer by selection within the scale £1350 to £1750 per annum.

All salaries are enhanced by a variable cost-of-living allowance, which at present is 20 per cent. on basic rates.

Full particulars may be obtained from the London Agent, Rhodesia Railways, 241, Salisbury House, London Wall, London, E.C.2.

Applications should reach the London Agent by the 11th December, 1953. E6213

ADMIRALTY

ROYAL NAVAL SCIENTIFIC SERVICE

SENIOR SCIENTIFIC OFFICER AND SCIENTIFIC OFFICER

Applications are invited for appointments in SENIOR SCIENTIFIC OFFICER and SCIENTIFIC OFFICER Grades in Experimental Establishments in London, Portsmouth, Weymouth and Gloucestershire areas and Scotland. The majority of posts are for Engineers and Physicists (particularly with Electronics), but there are a few posts for Physical Chemists and Metallurgists. Candidates must be British subjects with an appropriate First or Second-Class Honours Degree or equivalent high professional attainments. London salary inclusive of pay addition (men) S.S.O.s, £917–£1075, S.O.s, £440–£812. All appointments are unestablished (with F.S.S.U.), but with some opportunities to compete for established posts.—Application forms from M.L.N.S., Technical and Scientific Register (K), 26, King Street, London, W.1, quoting A 246/52/A/BH. E5861

PUBLIC APPOINTMENTS

GENERAL HOSPITAL
ROCHFORD, ESSEX

ENGINEER-IN-CHARGE

Applications are invited for the post of ENGINEER-IN-CHARGE at the above Hospital under the direction of the Group Engineer. Salary in accordance with Whitley Council Professional and Technical Council "B," viz., £575 by £20 to £655. The appointment is subject to National Health Service (Superannuation) Regulations 1950. The successful candidate will be required to pass satisfactorily a medical examination and will be required to act as Deputy to the Group Engineer covering all the hospitals in the Group.

Candidates must have served a recognised engineering apprenticeship, and hold a First-Class Board of Trade Certificate of Competency in Marine Engineering, or equivalent Naval Certificate; had sound experience in the maintenance and operation of steam and diesel power plant, generating alternating current electricity.

A modern semi-detached house is available for which a rent will be charged.

Applications, stating age, education, professional training, qualifications and experience, and accompanied by copies only of two recent testimonials and the names and addresses of two professional referees, to be sent to the undersigned at the Management Committee Offices, General Hospital, Rochford, by the 5th December, 1953.

J. C. FIELD,
Secretary.

E6227

RHODESIA RAILWAYS

VACANCY FOR ASSISTANT SIGNAL AND TELEGRAPH ENGINEER

A vacancy exists for an ASSISTANT SIGNAL AND TELEGRAPH ENGINEER for service in the Chief Engineer's Department of the Rhodesia Railways. Single men between the ages of 26 and 30 are preferred, but married men not over 30 years of age may apply.

It is desirable that applicants should have served with the British Railways in the Signal and Telegraph Communications Department and are Associate Members of the Institute of Railway Signal Engineers. It is essential that applicants have experience in the installation and maintenance of electrical and mechanical signalling and telecommunication equipment.

The grades of Junior and Assistant Engineer have salary scales between the limits of £560 and £1460 per annum, with incremental notches of £40 per annum, and the commencing salary would be determined in accordance with age and experience.

The vacancy is for appointment to the temporary staff in the first instance, but transfer to the permanent staff may be made to fill a vacancy and on the recommendation of the chief engineer.

All salaries are enhanced by a variable cost-of-living allowance which at present is 20 per cent on basic rates.

Full particulars may be obtained from the London Agent, Rhodesia Railways, 241, Salisbury House, London Wall, London, E.C.2. E6212

BRITISH ELECTRICITY AUTHORITY

EASTERN DIVISION

THIRD ASSISTANT ENGINEERS

Applications are invited for the following posts in the Generation (Construction) Department at Divisional Headquarters:—

THIRD ASSISTANT ENGINEERS.

Salary, Class AX/DX, Grade 3, 4 or 5, £681–£1086 per annum (including London weighting), depending on qualifications and experience.

Applicants should possess the Higher National Certificate or its equivalent and have had previous experience (a) in the design and installation of mechanical plant for generating stations and/or a knowledge of boiler and turbine design, or (b) previous experience in the preparation of schemes for switchgear, electrical auxiliaries, main and secondary cable installations and other equipment associated with modern generating stations. A knowledge of motor control equipment and of sequence interlocking systems would be advantage.

Applications, stating age, qualifications and experience, should be sent to the Controller, British Electricity Authority, Eastern Division, Northmet House, Southgate, N.14, to arrive not later than 12th December, 1953.

W. N. C. CLINCH,
Controller.

E6225

THURROCK URBAN DISTRICT COUNCIL

APPOINTMENT OF ENGINEERING ASSISTANTS, GRADE I

Two ENGINEERING ASSISTANTS are required on the staff of the Engineer and Surveyor, Mr. C. S. H. Hawkes, A.M.I.C.E., M.I.Mun.E., M.R.San.I., at salaries in accordance with Grade I of the A.P.T. Division of the National Scale of Salaries.

Candidates should have completed their training in a municipal or civil engineer's office.

The appointments will be subject to the Local Government Superannuation Act of 1937, and the successful applicant will be required to pass a medical examination. Applications, endorsed "Engineering Assistant I," together with names and addresses of three referees, should reach the undersigned not later than Monday, the 21st December, 1953.

Canvassing will disqualify and applicants must disclose in writing any relationship to any member or senior officer of the Council.

A. E. POOLE,
Clerk of the Council.

Council Offices,
Whitehall Lane,
Grays,
Essex.
21st November, 1953. E6236

PUBLIC APPOINTMENTS

MINISTRY OF SUPPLY

NATIONAL GAS TURBINE ESTABLISHMENT

MECHANICAL ENGINEERS, AERODYNAMICISTS, PHYSICISTS, CHEMISTS, METALLURGISTS AND MATHEMATICIANS

Ministry of Supply requires MECHANICAL ENGINEERS, AERODYNAMICISTS, PHYSICISTS, CHEMISTS, METALLURGISTS and MATHEMATICIANS for National Gas Turbine Establishment, near Farnborough, Hants. Those should be available in about six months for married men. Appointments according to qualifications and experience as Scientific Officer (1st or 2nd Class Honours Degree or equivalent in appropriate subject), £417–£781; Assistant Experimental Officer (Higher School Cert. (Science), or equivalent, Degree or H.N.C. may be an advantage), £264 (age 18)-£576; Experimental Officer (H.S.C., &c. but min. age 26, with suitable experience), £649–£799. Women somewhat less. Appointments unestablished. F.S.S.U. benefits may be available for S.O. class.—Application forms from M.L.N.S., Technical and Scientific Register (K), 26, King Street, London, S.W.1, quoting A 294/53/A. E6209

NATIONAL COAL BOARD

ENGINEERING BRANCH OF PRODUCTION DEPARTMENT

SENIOR DESIGNER-DRAUGHTSMAN

National Coal Board invite applications for the superannuable appointment of a SENIOR DESIGNER-DRAUGHTSMAN in the Engineering Branch of Production Department at London Headquarters.

Candidates should have had first-class experience of mechanical development, preferably in connection with colliery equipment, and be capable of supervising and checking the work of other draughtsmen; they should possess a minimum qualification of H.N.C.

Salary, according to qualifications and experience, will be in the inclusive range £652–£922 per annum.

Write, giving full particulars (in chronological order) of age, education, qualifications and experience (with dates), to National Coal Board, Establishments (Personnel), Hobart House, Grosvenor Place, London, S.W.1, quoting this paper and marking envelope TT/706. Original testimonials should not be forwarded. Closing date 12th December, 1953. E6220

THE EAST SURREY WATER COMPANY

APPOINTMENT OF DEPUTY ENGINEER

The Company invite applications from Corporate Members of the Institution of Civil Engineers, with a knowledge of waterworks practice, for the position of DEPUTY ENGINEER. The starting salary is £1500 a year, inclusive of cost-of-living allowance.

The person appointed will be required to pass a medical examination, to join the Company's pension scheme, and to live locally.

Applications, stating age, qualifications and experience, together with the names and addresses of three referees, must reach the undersigned not later than 12th December, 1953.

K. M. HEPBURN,
General Manager and Secretary.

London Road,
Redhill, Surrey. E6145

MINISTRY OF TRANSPORT AND CIVIL AVIATION

INVESTIGATING OFFICER

Applications are invited from men for TWO POSTS in the Civil Aviation Accidents Investigation Branch. H.Q. in London, but may be required to carry out investigation in any part of the world. Age at least 30 on 31st December, 1953. Candidates must be of good education, able to compile technical reports and have had wide experience of aeronautical engineering and inspection up to aircraft maintenance engineer's licence endorsed "B" or "D" standard. Flying experience an advantage. Inclusive salary £623, rising to £760. Posts are unestablished, but may have long-term possibilities. —Application forms and particulars from Ministry of Transport and Civil Aviation, Establishments/Staffing B.1, Berkeley Square House, London, W.1. Application forms to be returned by 17th December, 1953. E6208

ELECTRICAL ENGINEERING POSTS

CENTRAL ELECTRICITY BOARD FEDERATION OF MALAYA

A number of ELECTRICAL ENGINEERING POSTS (various categories) are vacant in the above Board. Salaries, &c., between £1197 and £7730, according to experience and dependants. Option of appointment (a) on agreement for three years, with prospect of permanency, or (b) on contract for three years, with gratuity of £200/£280 a year. Option to terminate appointment at end of first year in both cases if desired. Free passages; liberal leave on full salary. Candidates, preferably Grads. or Corp. Members of I.E.E. or I.M.E., must have sound training and appropriate experience. It will be possible to preserve superannuation rights in certain cases.

Write to the Crown Agents, 4, Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience, and quote M2C/28770/EH. E6189

THE ENGINEER

NOVEMBER 27, 1953

Shortage of Engineers

SPEAKING at a meeting of the Court of Governors of Manchester University last week, Lord Simon of Wythenshawe stressed the importance of science and technology in the expansion of industrial development in this country. He said that up to 1890 this country was ahead of the U.S.A. measured in terms of output per man year. Since then, output per man year had increased in this country by an average of 1½ per cent a year, which meant that it had just about doubled in the last sixty years. In the same period in the U.S.A., however, output per man year had increased by 3 per cent a year, and was now two and a half times as great as in this country. Lord Simon went on to say that, fundamentally, the one essential in this steady and continuing trend was the amount of scientific research and teaching, and the number of scientists and engineers in industry. For every engineer turned out by our universities, the American universities were turning out twenty, and they were all absorbed by industry. Thirty years ago, Lord Simon continued, the engineering industry had quite failed to realise the importance of employing university graduates, but that situation had now changed. At present, there was a very serious shortage of engineering graduates and twice the number being turned out would be immediately absorbed by industry. The most difficult problem, Lord Simon added, was the schools. Last year 200 places available for engineering students in universities and colleges had not been filled for lack of suitable applicants. That was partly because of the lack of science teachers, and partly because the heads of grammar schools were not as a whole yet convinced that engineering offered an important career for boys. The whole of our social services, Lord Simon commented, depended upon the output of industry, and as far as the universities were concerned, the output of industry depended upon the output of scientists and engineers.

Ventilation in London Tube Railways

SOME notes have been issued by London Transport in connection with work now nearing completion to improve ventilation of the southern section of the Northern Line. It is pointed out that the adequate ventilation of the tube railways of London has been a major problem for almost as long as the railways have been in existence, and the present installations provide a capacity sufficient to change the air in the entire system three times an hour. The main ventilating problem which has grown over the past thirty years arises from the storage of heat in the clay round the tunnels. From about 1920 it was apparent that tube temperatures were slowly and steadily rising, a condition due to the increasing heat input consequent upon more intensive train services, combined with thermal storage in the earth surrounding the tunnels. From time to time programmes of ventilation improvements were undertaken, with a view to removing more of the heat generated. A survey made in 1949 indicated that, whereas the average annual temperature on all tube lines was 73 deg. Fah., the average at stations on the southern section of the Northern line, i.e. from Kennington southwards, was 76½ deg. Fah., with particularly "hot spots" at Kennington, Balham and Oval. The present works have been carried out to reduce the temperatures at these particular stations and also bring about a general lowering of the overall temperature throughout the whole section of line. Under this scheme the initial requirement was for two large additional interstation fans, of modern design, at Kennington Park and Balham substations. However, as the effect of such new installations by themselves would have been to intensify the velocity of draughts at the nearby Oval and Balham passenger stations, the opportunity was taken to sink draught relief shafts at both stations. Now both shafts have been completed and one of the new fans is installed, and it is stated that already a noticeable improvement has been recorded in the overall ventilation.

Winter Prospects of Inland Transport

THE Winter Transport Central Joint Conference, which was first set up in 1951, recently held its customary meeting to review the prospects of inland transport during the coming winter. This meeting was attended by senior representatives of the British Transport Commission, the Association of British Chambers of Commerce, the Federation of British Industries, the National Union of Manufacturers, and the National Farmers' Union. At the conference it was pointed out that British Railways have so far this year carried a million tons of iron ore, 800,000 tons of steel, and nearly 3,500,000 tons of coal more than in the corresponding period of last year. During the coming winter, it was stated, British Railways expected to carry over 180 million tons of traffic of all classes or nearly 2,500,000 tons more than last winter. The Inland Waterways had a margin to spare and British Road Services was working well within its capacity. If it was needed to overcome local difficulties during the winter, co-operation between the Commissioners' rail and road services was assured as, under the programme agreed with the Road Haulage Disposal Board, the actual handing over of vehicles purchased will not begin until February next. The conference agreed that, given normal winter weather, all traffic which required transport by rail could be accepted and moved without delay. A report issued after the conference points out that railway operating efficiency and favourable working conditions last winter made it unnecessary to call upon the forty-four district committees set up in 1951. The conference, however, welcomed the Transport Commission's policy of maintaining the closest possible liaison with its customers, and decided to keep the nation-wide organisation in being, so that, if necessary, local co-operative action could be taken at once.

Royal Society of Arts

ON Wednesday of last week the two-hundredth session of the Royal Society of Arts was inaugurated at a meeting in London at which the chair was taken by H.R.H. The Duke of Edinburgh, the president of the Society. Some preliminary details of the Society's plans for celebrating early next year the bicentenary of its foundation were given in our issue of October 16th. Speaking at last week's meeting, the Duke of Edinburgh said that the original pioneering atmosphere of the Society still continued to be strongly apparent. The Society was not concerned with art for art's sake, but with the application of art to the improvement of the design of manufactured articles. That duty, His Royal Highness added, was as important now as it had been in the eighteenth century. At the meeting an announcement was made about a competition which the Society is organising as part of the bicentenary celebrations. Prizes totalling £500 are being offered for conceptions of life on this planet in the year 2000, and forecasts, in visual or written form, are invited of the future developments which may be looked for in some particular aspect of life related to arts, manufactures and commerce, the field of the Society as defined in its full and original title. It is stated that the chief criterion in assessing the entries will be originality. Full terms and conditions relating to this competition, together with registration forms, may be obtained from the Royal Society of Arts, John Adam Street, London, W.C.2.

Institution of Gas Engineers

AT a luncheon in London on Tuesday last, which was organised by the Institution of Gas Engineers, Sir Ben Lockspeiser, secretary of the Department of Scientific and Industrial Research, spoke on "The Gas Industry and the Future." He said that the gas industry contributed virtually nothing to the annual output of some 2,500,000 tons of smoke and grit, and, as far as could be estimated, only 2 per cent of the 5,000,000 tons of sulphur dioxide put into the atmosphere annually came from the gasworks. If smokeless zones became fashionable, Sir Ben added, the gas industry would have a big part to play. Sir Ben went on to speak about the use of fines and ungraded coals for gas making, and said that there were good grounds for believing that the extremely important problem of using coal, in size or quality, hitherto considered to be of little value in gas making, would be brought to a successful practical conclusion. He then referred to natural gas, commenting that though the potentialities in this country might appear to be small, they should not be disregarded. There was enough evidence of natural gas in various places in Great Britain, Sir Ben continued, to make its exploitation a reasonable success. Furthermore, according to the evidence of the Geological Survey, features of rocks underlying parts of Eastern England were such as to encourage the hope that rocks producing gas, and structures capable of acting as reservoirs, might be found by a programme of exploratory boring. If underground reservoirs were found, they might serve in the future as valuable storage for meeting peak loads.

Flood Protection on the River Thames

AT a meeting held on November 17th, the London County Council decided to send a statement of evidence on the systematic protection of London against floods to the Departmental Committee of Coastal Flooding (the Waverley Committee). It is pointed out in this evidence that since 1930 London's flood defences have been sufficient to cope with all tides up to that of February 1, 1953, when the defences from London Bridge to Woolwich were topped by amounts of up to 5in; high water level in Central London was within ½in of flood prevention level. The Council points out that the raised flood banks in Kent and Essex are now appreciably higher than the standard flood prevention level in the eastern parts of the County of London, and the height of some of those defences in the Thames estuary has caused the Council grave concern, and emphasised the arguments for setting up a joint authority to deal with problems of flooding. In addition to proposing the formation of such an authority, the L.C.C. also drew the attention of the Waverley Committee to the possibility of reducing the effects of abnormally high tides by building breakwaters across the estuary, with an opening for shipping in the navigation channel. The effectiveness of, and provision of, overspill areas both up and downstream of London, and also the construction of a dam across the estuary westward of the Isle of Grain, with a small opening in the navigation channel to provide facilities for shipping, should, in the opinion of the L.C.C., be investigated. Another matter which merited further investigation, the Council thought, was the probability of the recurrence of high tides due to storm surges and the effect on the height of tides of the subsidence of South-Eastern England.

Reconstruction of the Brooklyn Bridge

(By our American Correspondent)

The Brooklyn suspension bridge was opened to traffic on May 24, 1883. The need for certain alterations in the suspended structure became evident some time ago, and the New York City Department of Public Works has now completed the reconstruction of the span, eliminating the original tramway and electric railway tracks to create a three-lane carriageway in each direction. The reconstruction work was planned to avoid changing the distinctive character of the bridge.

THE Brooklyn suspension bridge is of considerable historical interest to engineers. It was the first suspension bridge to be built over the East River, connecting the boroughs of Brooklyn and Manhattan of New York City, and was opened in 1883. That fact was noted in THE ENGINEER of June 1, 1883, where the bridge was described in an article which opened thus :—

"The Great East River Bridge uniting New York and Brooklyn was opened on Thursday, the 24th of May. One hundred thousand people, it is said, passed over it during the first twelve hours, which is not surprising. The people of New York and Brooklyn bear much the same relation to each other that those of Middlesex do to those of Surrey as far as London is concerned. If all communication had had to be carried on by ferry until the 24th of May, it may be imagined that considerable interest would be taken in the opening of a bridge across the Thames."

The bridge construction, we noted at that time, was a work of enormous difficulty and constant delays, and dissensions broke out frequently and the two cities were often at loggerheads ; the projectors kept steadily on, however, and ultimately surmounted every obstacle. The Brooklyn Bridge is shown in the illustration, Fig. 1.

When John A. Roebling made his original plans for the bridge in 1857, he could not possibly have anticipated the demands which vehicular traffic would eventually make upon the structure. In his day, it was of major importance to carry people in and out of Manhattan by suburban trains, and the original cross-section of the suspended structure was well conceived for this purpose. The tracks for the trains were situated between pairs of deep stiffening trusses, and the inner trusses, adjacent to the inner rails, distributed the train loads along the inner cables (see Fig. 2). The intermediate trusses, adjacent to the outer rails, distributed the train loads among the transverse floor beams which, in turn, carried the loads to the outer shallow trusses. The intermediate trusses, furthermore, acted as effective protective barriers between the trains and the vehicular traffic. To keep pace with the rapidly increasing population of Brooklyn, the original two-car trains were soon lengthened to four and five cars. In 1898, additional transport was provided by trams, whose lines were situated adjacent to the intermediate trusses, as indicated in Fig. 2. With the building of tunnels for the underground railway under the East River, patronage dwindled to such an extent that the suburban electric trains over the bridge were discontinued in 1944. The trams were then run over the train tracks, leaving the roadways for the sole use of vehicular traffic. The roadways, however, were only 16ft 7¼in wide, which was too narrow for modern traffic. The municipal authorities of the City of New York thus found themselves with a bridge which was no longer needed to carry suburban trains and was inadequate to carry the vehicular traffic prevailing.

The need for the reconstruction of the Brooklyn Bridge had long been recognised. As far back as 1903, Gustav Lindenthal, then commissioner of bridges of New York City, presented a plan, saying: "The present structure was never intended and dimensioned for the traffic it has to bear now. The suspended structure, from anchorage to anchorage about 3600ft long, is in a worn-out and weakened condition, requiring constant and expensive repairs to keep it safe. The rebuilding of the bridge has become imperative."

Since then four more bridges have been added over the East River to carry the constantly increasing highway and suburban train traffic, and the adjacent bridges have been carrying much of the traffic that would logically use the Brooklyn Bridge if its capacity permitted. In spite of high maintenance costs and the recognised need for a major reconstruction, funds were never available, and the structure remained in service without any substantial improvement, carrying as much as three times the load for which it was originally designed. In 1948, the municipal authorities finally decided to have the bridge reconstructed to meet modern traffic needs, by increasing its highway traffic capacity to six lanes.

Bridge Design

The bridge has a main or river span of 1595ft 6in and two side or land spans of 930ft each. These spans are supported by four 15¾in diameter cables containing 5296 galvanised wires of 1·65in diameter. The stiffening trusses of the suspended structure pass through the towers where they are rigidly fixed against all motion. The trusses are pin connected to the anchorages. The bridge is "five-hinged," counting the pin connection at each anchorage and a slip joint at each mid-span. The expansion or slip joints are situated in the stiffening trusses at the centres of the land and river spans. This arrangement of slip joints at mid-span was necessitated by the incorporation of the system of diagonal stays radiating from each tower top to points of attachment in the bottom chord. The slip joints cannot transmit bending moment, but do transmit shear by means of tongues projecting across each slip joint from the top and bottom chords on one side of the slip joint to the chords on the other side. The stiffening trusses are connected to the cables by wire rope suspenders spaced at 7ft 6in centres, which is the general spacing of the floor beams. In addition to these suspenders, the portions of the stiffening trusses adjacent to the towers are carried by the diagonal rope stays which originate at the tower tops and fan out to connect to the bottom chords of the stiffening trusses at 15ft centres. The stiffening trusses are "quadruple intersection Warren trusses." A vertical section anywhere between the verticals at the panel points will cut four eyebar web members. The members that slope downward toward the river are termed "diagonals" and are fixed in length. The members that slope upward toward the river are termed "counters," and are adjustable by sleeve nuts.

The entire system of cables, diagonal stays and stiffening trusses is highly redundant, rendering accurate stress analysis difficult and involved. A change in adjustment of any one member produces a readjustment of stresses in other members and affects the vertical curvature and alignment. From the point of view of cable loads, it has been found that a particularly interesting condition exists on the Brooklyn Bridge. The small steel rollers under the saddles on top of the towers of the bridge have never functioned as intended. The rollers simply have not rolled. They have become skewed, imbedded and rusted, virtually "frozen" from the start. As a result, unbalanced cable pull on the tower tops, from unsymmetrical loading or thermal expansion of the cables, has produced serious bending strains in the towers, tending to, loosen joints in the masonry. The cumulative unbalanced pull on the tower tops has repeatedly caused the cables to overcome their friction and to "jump" in their saddles, thereby alarming the public, but, actually, producing a readjustment of strain and a relief of stresses. In 1922, two of the main cables on the Man-

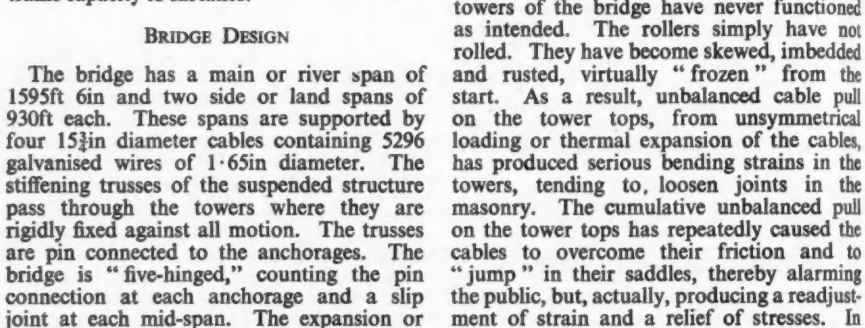


Fig. 1—The Brooklyn Bridge

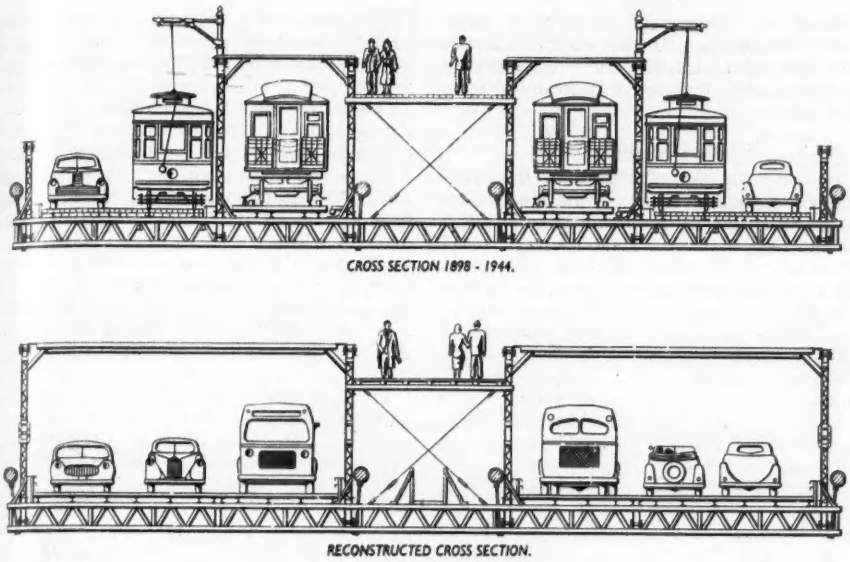


Fig. 2—Bridge Cross Sections

hattan tower slipped in the saddles and moved toward the river by ½in and 1¾in respectively, thus giving evidence of excessive unbalanced cable pull. Fortunately, the bridge towers rest on compressible timber cushions formed by the roofs of the caissons on which they are founded. These massive timber cushions are 15ft thick under the Brooklyn tower and 22ft thick under the New York tower. The elastic compressibility of the timber cushion permits the masonry tower to rock on its base, thus relieving the strains in the masonry due to unbalanced cable pull. Precision surveys have shown that the deflection graph for each tower is a straight line, as in a hinged column, and not a curve, as in a cantilever beam. Fig. 3 shows a detail at the top of one of the towers, which is reproduced from our article of 1883, and is of particular interest in illustrating these remarks.

Design Changes

In planning the reconstruction of the bridge, the major change that was necessary was the simplification and the rearrangement of the stiffening trusses. As shown in Fig. 2, the bridge was built with four cables and six stiffening trusses, the two inner trusses were 17ft deep, two intermediate trusses, 17ft deep, and two outer trusses, only 8ft 9in deep. The inner and outer trusses were situated underneath the four cables, but the two intermediate trusses had no cables above them to which they could transmit their share of the total load, resulting in an arrangement which impaired the efficient functioning of the structure as a whole. Furthermore, the intermediate trusses interfered with the desired clear roadway width of 30ft, leaving a roadway width of only 16ft 7½in. The wide American cars could barely squeeze two abreast through such a restricted width and, in actual use, it was only a single-lane roadway. Both necessity and efficiency required, therefore, the removal of the two intermediate trusses, thus simplifying the cross section by reducing the number of stiffening trusses from six to four, and, at the same time, yielding two clear roadways, each 30ft wide, or a total of six highway lanes for vehicular traffic. The rearrangement of the cross section, which is illustrated in Fig. 2, also called for the deepening of the two outer trusses from their half-depth of 8ft 9in to the same full depth, 17ft, as the other trusses, so that the outer trusses could take their proper share of the total load and transmit that share effectively to the cables above them. The combined effect of the change was equivalent to removing the full-depth intermediate trusses from their ineffective and objectionable intermediate position and transferring them to replace the inadequate half-depth trusses under the outer cables. The half-depth outer trusses were left in place, but were built up to the full depth by utilising salvaged top chords from the scrapped intermediate trusses. The new eyebars which were placed in the outer trusses were all carefully adjusted with the aid of strain gauge measurements.

As indicated in the drawings, each stiffening truss has an intermediate chord, consisting of one or two longitudinal 6in channels, sitting on top of the floor beams and riveted to the vertical posts of the stiffening trusses. In removing the intermediate trusses, the bottom chords were left in place for participation in resisting the horizontal thrust from the diagonal stays, and the intermediate chords were also left in place to form the top chord of a new distributing truss to aid the floor beams. The intermediate trusses were removed by flame cutting the diagonals and counters close to the pins, and flame cutting the vertical posts at the tops of the intermediate chords. The intermediate trusses, although they were not directly suspended from any cables, performed the valuable function of distributing the effect of concentrated floor loads. With the intermediate trusses completely removed, each floor beam would have to carry its wheel loads without help from adjacent floor beams, an arrangement which would have resulted in overstressing the floor beams. To improve this condition, light diagonal members were added between the retained bottom chords and intermediate chords. In this manner, stiff distributing trusses were formed which reduce the stresses in the floor beams due to concentrated wheel loads by 50 per cent.

The live load originally proposed for the reconstructed bridge was 40 lb per square foot of roadways or 2400 lb per lineal foot of bridge, based on an unchanged value of the dead load. Actually, the reconstruction of the bridge increased its weight by 400 lb per lineal foot, or about 7 lb per square foot of roadway. Allowing a further 8 lb per square foot for unforeseen additions, there is left an allowable live load of 25 lb per square foot. This is an ample figure when it is considered that traffic on the bridge will be restricted to passenger automobiles. A comparison between the average dead loads of the bridge, in pounds per lineal foot, before and after reconstruction, is given in the following table :—

	Before reconstruction	After reconstruction
For each outer cable	2220	2400
For each inner cable	2500	2520
Total load for bridge	9440	9840

The total dead load of the bridge has been increased by about 4 per cent, but the division of dead load between the inner and outer cables has been more nearly equalised. The maximum dead load per cable, taken by the inner cables, has been increased by less than 1 per cent.

Stress Analysis

The degree of redundancy of the cables and stiffening trusses of the bridge may be visualised by starting with the simplest components of the bridge and then adding the parts required to build the bridge up to its full form. Basically, the bridge is formed of trusses fixed rigidly to the towers and cantilevering half-way into the land and river spans. In each land span, a simple truss is placed between the end of the cantilever and the anchorage. In the river span the two cantilevers are pinned together at mid-span, forming the first redundancy. Then the cables and suspenders are added, which are considered as forming the second redundancy. Finally, the diagonal stays are added, each stay adding a redundancy. To simplify the effect of the stays, they were combined into three groups at each side of the towers. Thus, according to these assumptions, each land span had four redundancies, and the main span had eight redundancies. The equations involving these redundancies did not yield the exact stresses, as they took no account of the distortion of the structure, which alters the computed stresses. Instead of determining the effect of distortion by extended mathematical treatment, deflection and stress measurements were made on the bridge under train loads and compared with the values computed from the equations.

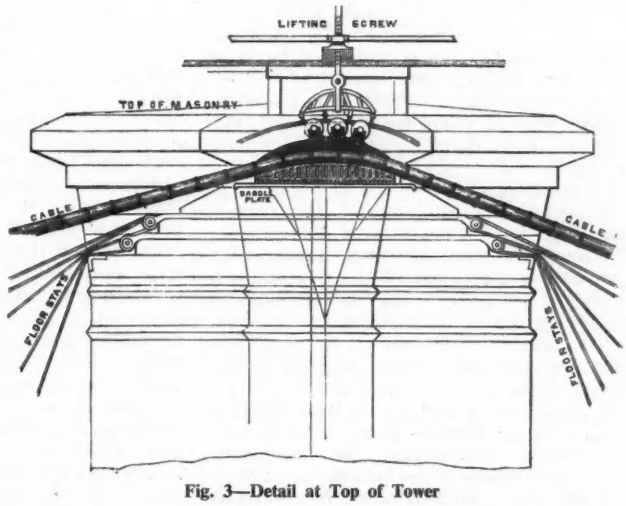


Fig. 3—Detail at Top of Tower

The experimental data thus obtained provided checks on the computations and furnished correction factors to apply to the computations to account for the distortion of the bridge under load.

A careful analysis of the stresses in the stiffening trusses indicated high compressive stresses in the bottom chords in the regions of the diagonal stays. These high stresses were produced by the superposition of thrust reaction from the diagonal stays upon the stresses from the normal truss action.

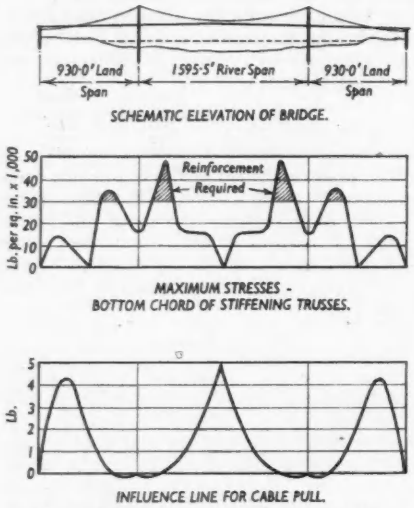


Fig. 4—Stiffening Truss Stresses and Cable Influence Line

The maximum stresses in the bottom chord, before reinforcement, are shown in Fig. 4. It was decided to reinforce the bottom chords in the overstressed regions where the calculated stresses exceeded 30,000 lb per square inch. The regions in which the bottom chords required reinforcement extended between panel points 17 and 45 in the land spans and between panel points 17 and 42 in the river span. The existing bottom chords between panel point 17 in the land span and panel point 17 in the river span are of double depth, each half-section consisting of a 9in channel set on top of another 9in channel with webs vertical. The regions requiring reinforcement were beyond the double-depth chords, thus calling for lengthening the extent of the double-depth chords. Instead of using 9in channels to be set on top of the existing 9in channels, it was decided to use 8in by 4in angles for the new material. With suspenders and diagonal stays in the way, it was found that the angles were easier to erect than channels. To make the bottom chord reinforcement effective in sharing stress, it was applied when the stresses in the bottom chord were reduced to as low a value as the controlled removal of the dead load of the original floor permitted.

Within the main towers, the bottom chords are in contact with the tower masonry on one side, and close to masonry ledges on the underside. The pockets thus formed were holding dirt and moisture and were causing considerable corrosion of the lower flanges of the bottom chords. Cramped quarters made the general reinforcement by riveting impracticable, and the compression stress in the bottom chord precluded the use of welding. At the faces of the towers, where cutbacks in the tower masonry provided room for riveting, the lower flanges of the bottom chords were reinforced locally to rest on new bearings. Between the bearings the lower chords were cleaned thoroughly and encased in concrete. The concrete was carried up high enough to serve as kerbs for the roadways. In this way, the chords are stiffened to increase their load-carrying capacity, while they are also protected from dirt and moisture.

Reconstruction Work

In planning the rebuilding of the outer trusses, it was feared that, if the trusses were to be unpinned, variations in the adjustment of the suspenders and diagonal stays would then be free to distort the deck. To avoid such unpredictable complications, the method adopted for building up the outer trusses was one that did not require dismantling of the existing trusses. The details of the built-up outer trusses are shown in Fig. 5. Holes were cut in the cover plates of the old top chords to permit the insertion of new gusset plates, recessed to avoid interference with the old posts. New diagonals and counters and extensions of the posts were attached to the new gusset plates. The extensions of the posts were spliced to the old posts by 7in channels, which straddled the old chords and were bored to take the old top chord pins. The top chords of the built-up trusses were salvaged from the dismantled intermediate trusses. It was required to fabricate special new top chord sections at the towers, because interference from the masonry prevented the use of the old sections. The new diagonals and counters were made adjustable to accommodate them to variations in dimensions of the old structure.

The roadways of the bridge were originally of light construction, consisting of timber planks, which were later replaced with wooden paving blocks. This original lightweight construction limited the permissible dead load of any new construction and eliminated the use of a conventional modern reinforced concrete slab. The authorities recommended the use of an open steel grid for the new roadways, so as not to increase the dead load of the bridge and because the open grating would eliminate snow removal and sanding. However, while asking for an open grating for the roadways in the main span over the river, the officials insisted upon a solid floor construction in the land spans. More than half the area under the two land spans comprises streets, open docks and uncovered industrial space, and the authorities feared that this area would be menaced by objects falling through the open grating. The proposed combination of open grating in the river span with solid slab in the land spans was, however, impracticable, for the unbalanced dead load in main span and side spans would have produced a serious unbalanced cable pull on the towers. The adoption of a uniform roadway construction for the three spans was therefore recommended, and it was finally decided to use a closed floor of the lightest available kind. The new roadway slab consists of 3in "I-beam-Lok" steel grating made by the United States Steel Corporation, with a special arched sheet steel pan mounted under each square of the mesh to reduce the volume of concrete. The widest spacing of stringers is only 3ft 6in which makes the "I-beam-Lok" flooring strong enough, even without the concrete filling, to carry trucks weighing more than 20 tons. To expedite the reconstruction work, a construction joint was placed in the floor slab along the centre stringer of each roadway. The contractor was thus able to work from the old roadway and complete all demolition and construction adjacent to the inner trusses. Then, working from the new half-roadways, he completed demolition and construction adjacent to the outer trusses.

The reconstruction of the roadways required a complete new set of longitudinal stringers. The new roadway stringers are 8in standard American I-beams. Their span is short, the floor beams being spaced at a pitch of 7ft 6in. They were chosen to provide the standard American headroom of 14ft for vehicular traffic, and to have strength consistent with that of the floor slab. The depth of the new stringers is the same as that of the old stringers under the train tracks, and it was hoped that the track stringers could be used under the new roadway. It was found, however, that corrosion of the top flanges under the track ties was far advanced, and the idea of using the old track stringers had to be abandoned. The new stringers were provided in 30ft lengths and were erected with staggered joints. In the regions of the diagonal stays, the stringers and floor slabs have no expansion joints, thus permitting the floor to participate in resistance to thrust from the diagonal stays, and also providing lateral stiffening for the unbraced bottom chords. Outside the regions of the diagonal stays, the stringers and floor slab are provided with expansion joints at 90ft intervals. A photograph of one of the completed new roadways of the bridge is reproduced in Fig. 6.

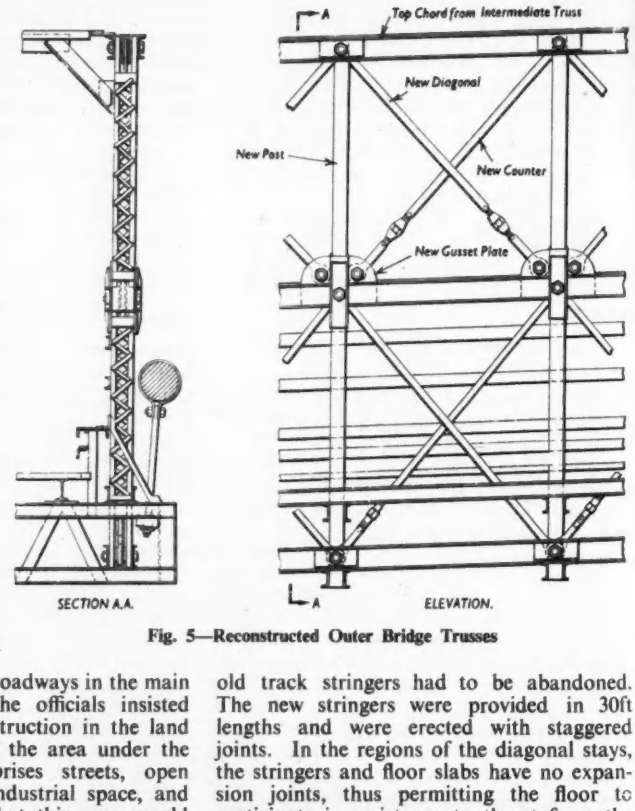


Fig. 5—Reconstructed Outer Bridge Trusses

The connections and bracing which held the original shallow outer trusses upright were considered inadequate when the outer trusses were raised to the height of the inner trusses. The flexibility of the elongated web members rendered the new top chords liable to lateral buckling under the com-

pressive stresses imposed by live load. To eliminate this hazard, the new top chords were tied by stiff struts to the top chords of the inner trusses which, in turn, are braced by the promenade construction (Fig. 6). The new top struts consist of two channels forming a T-section. The vertical channel provides vertical stiffness. The horizontal channel provides lateral stiffness for the compression flange. Knee braces at the

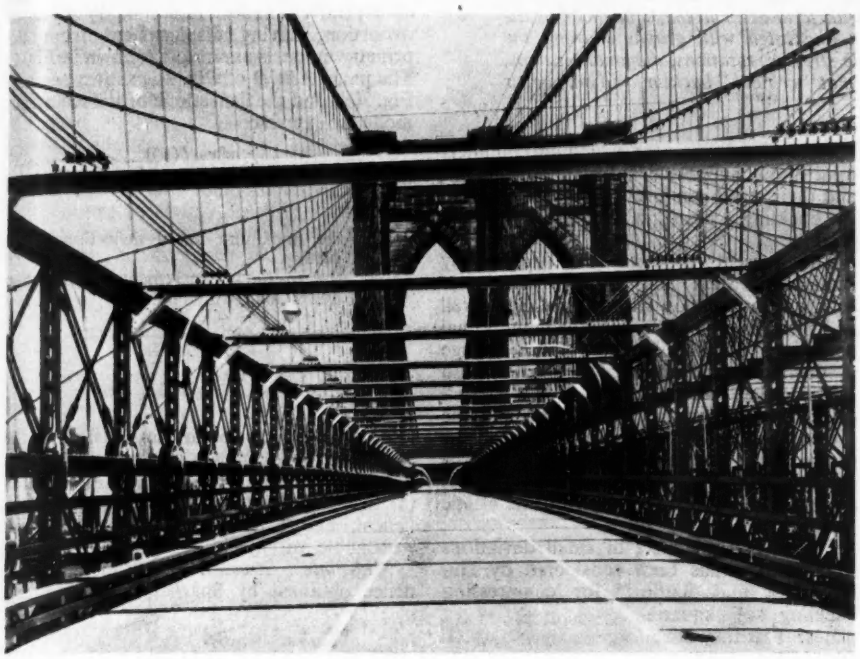


Fig. 6—Reconstructed Roadway

trusses provide open spaces, to facilitate any future removal of pins from the top chords. At the towers, special sections were required for the struts to support the promenade where it divides to pass through the masonry arches at the level of the top chords.

The timber promenade has been a very popular feature of the Brooklyn Bridge. It has served and given pleasure to countless thousands through the years, but, at the same time, it has been a great nuisance from a maintenance point of view. In the course of the reconstruction of the bridge, the timber promenade and its supporting stringers required complete replacement, and due consideration was given to the use of permanent and fireproof materials. All substitutes for timber, however, increased the dead load, and the dead-load problem had already been made acute by the adoption of a closed roadway slab. For this reason, as well as to preserve the tradition of the design, it was decided to retain the timber flooring for the promenade. The new promenade comprises stringers which are creosoted for preservation, and planks which are salt-treated for fire prevention. The opportunity was taken, after removal of the old promenade, to replace with steel all timber supports under the stringers.

The New York City Department of Public Works had requested the consulting engineer to avoid the use of welding as much as possible, and, accordingly, the details in the contract drawings for the reconstruction of the bridge were made up entirely with riveted connections. This limitation was especially restricting, because of the inconvenient dimensions of the old steel channels of the bridge members. Compared with modern American channel sections, the old steel channels in the structure have thicker webs and narrower flanges. Rivets through the old channel flanges necessarily had to be small and were difficult to drive. The fastening of the new longitudinal stringers to the top chords of the old latticed floor beams presented a problem. The top chords of the old floor beams consisted of two 6in channels, back to back, with flanges horizontal. It was impossible to drive rivets through the channel flanges, because of their narrowness, and, in addition, because of the presence of web reinforcing plates between the channel flanges. Connection between the new stringers and the old floor beams was accomplished with clip angles, which were riveted to the vertical webs of the channels that form the top chords of the old floor beams. When work started, it was found that drilling holes for rivets in the old floor beams was a very slow and difficult process. It seemed that the old steel had developed hard spots which resisted and dulled the drills. Finally, to expedite the work, the contractor's proposal to weld the new stringers to the old floor beams was accepted, and the clip angles were eliminated.

The distributing truss, which was field riveted in the south roadway, was almost entirely field welded in the north roadway. With the exception of the work on the outer trusses and the reinforcement of the bottom chords of the four trusses, welding was substituted for riveting as the work progressed, with consequent saving in weight of material and in construction time.

It was realised that, with the main cable saddles frozen at the tower tops, the heavy masonry towers acted as anchorages to resist the unbalanced cable pull caused by load and temperature changes. Realising the objectionable effects of unbalanced cable pull, a procedure for demolition and erection was included in the engineering specifications to maintain a balance of cable pulls in the land and river spans. The computations were based on the influence lines for cable pull in the respective spans, which are shown in Fig. 4. The ordinates to the influence lines show the cable pull produced by the addition or subtraction of 1 lb of load at any point on the bridge. The influence lines indicated that work had to proceed simultaneously at four points on the bridge, situated symmetrically about the towers. The south roadway of the suspended spans was reconstructed, with its stiffening trusses, while one-way traffic was maintained on the north roadway. The reconstructed south roadway was opened to traffic in May, 1951, and the north roadway was then closed for reconstruction. The latter was completed in May, 1952, but could not be opened to traffic until the reconstruction of the north roadway of the bridge approaches had been completed.

The reconstruction scheme was executed under the direction of F. H. Zurmuhlen, Commissioner of the New York City Department of Public Works, and J. F. Johnson, Director of its Bridge Division. Dr. D. B. Steinman, of New York City, acted as consulting engineer, and supplied the data and illustrations used in this article.

Mechanised Drifting

We have received from the National Coal Board particulars of two systems designed to speed up mine drifting and lower mechanical and maintenance costs by the use of "shuttle conveyors" which have been devised by Mr. C. Rudge, Mechanisation Engineer of No. 3 Area of the Board's North Eastern Division.

The first system, which has been operated in a 16ft by 10ft drift at Manvers Main Colliery, uses two "Eimco 21" rocker shovels with a retractable shuttle conveyor running in between them. A boom carrying three drills is mounted on a bogey which runs in channel irons fixed to the conveyor structure. After a round of holes has been drilled the bogey is run back to the delivery end of the shuttle conveyor and the rocker shovels are brought up to the face. Attached to the rear end of each shovel is a right-angle chute mounted on wheels and running on the shovel's track. Each chute receives the broken stone from its shovel and delivers it on to the shuttle conveyor. The conveyor, which in turn delivers on to a main or gate conveyor, is also mounted on rails and has a small haulage winch to pull it to and from the face. The conveyor frame is fitted with a "V" shaped plough which clears a path as the conveyor moves up to the face. It is stated that over a period of six months teams of four men each shift, three shifts a day, working the system at Manvers Main drove an average distance of 28 yards a week.

In the second system a single "Eimco 40" rocker shovel is used for loading stone direct on to the shuttle conveyor in narrower headings. The shuttle conveyor is mounted on wheels and runs on the same track as the shovel. It is 19ft long and attached to the shovel by a drawbar. The conveyor's mounting is high enough to allow it to run over the tail end of the gate conveyor. A small chute is fitted to the delivery end of the shuttle conveyor so that the stone is off-loaded with a minimum of shock. With this equipment only two men are employed at the face, and over a period of twelve months an average advance of 14 yards a week has been obtained on two-shift working.

Work Study Courses.—We are informed by Production-Engineering, Ltd., 28, Bruton Street, London, W.1, that it proposes to conduct training courses in work study and management. The first course will start on June 18, 1954, and will be followed by two more on February 15th and March 15th. Each course will last three and a half weeks and will give a grounding in time and motion study, a training in the use of these techniques by management and background training in self-expression and clear thinking. Three-day courses for senior executives will also be held for those who desire a survey of the use of work study for management.

Post Buckling Behaviour of Long Square Boxes under Torsion

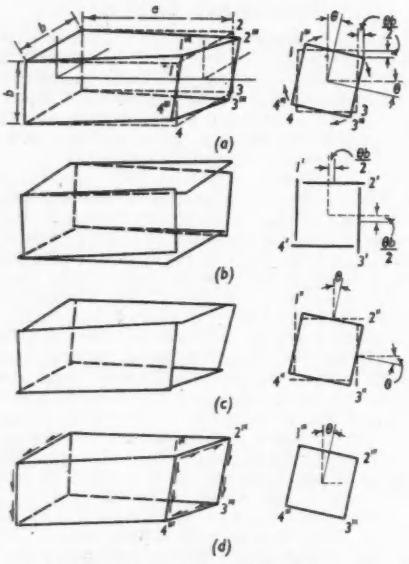
By B. H. FALCONER, B.E., Ph.D., D.I.C.

This article describes a theoretical study of the non-linear behaviour in torsion of long, uniformly thin-walled, unstiffened boxes of square cross section. An approximate solution has been obtained by considering the strain energies of stretching and bending of the wall plating which would be associated with an assumed mode of buckling. An allowance for the influence of initial deviations from planarity of the plating has been made by considering them to occur in the same mode as the deflections due to load. The solution is illustrated with graphs showing the buckling deflections, longitudinal membrane stresses, rotations, diagonal tensions, and maximum surface stresses. It is shown that "critical" buckling will only occur when the plating is initially perfectly flat.

FROM the Bredt-Batho[1] theory of torsion it can be shown that the walls of boxes of the kind considered should be subject to uniform two-dimensional shear stress. An approach to the present problem may be made, therefore, by considering a plate of dimensions equal to a side of a square box which is subjected to uniform shear tractions along its edges. Southwell and Skan,[3] in an exact analysis, have given the value of applied shear stress at which an infinitely long simply supported flat plate will buckle, and their result can give a close indication of the buckling stress for a long box having flat plating.

The present problem was treated by Budiansky, Stein and Gilbert,[4] but their solution, in common with that of Southwell and Skan, is applicable only for infinitesimal deflections of the plating, because change in the membrane straining associated with buckling has been ignored. No "large" deflection solution has been found and the present study was made as experiments showed that both the presence of large deflections and an initial lack of flatness can have an appreciable effect on the elastic behaviour.

The theoretical effect of small deviations from flatness has been considered by Hu, Lundquist and Batdorf[6] for compression buckling of square plates. This they have done after amending Von Karman's equations[2] to allow for the influence of initial deflections occurring in the same mode as the deflections due to load. However, solutions based on Von Karman's equations have been obtained only in relatively few cases, because of mathematical difficulties, and so, for the present problem, a simplified approach was sought.



(*a*) Twisting of a box under torsional loading.
(*b*) First stage : body movements of isolated plates.
(*c*) Second stage : torsion of individual plates.
(*d*) Third stage : application of shear flows around plates to regain continuity at corners.

Fig. 1—Simple Torsion of an Elastically Stable Box

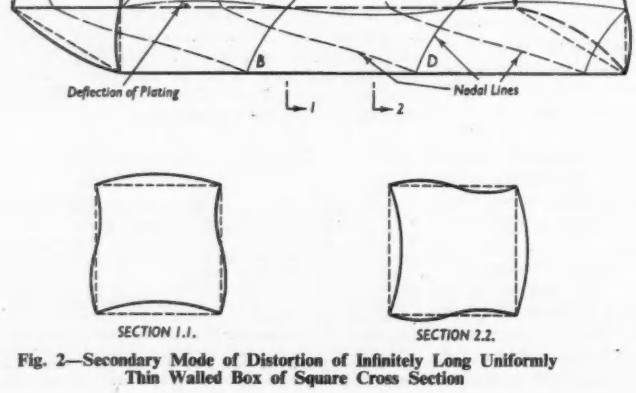


Fig. 2—Secondary Mode of Distortion of Infinitely Long Uniformly Thin Walled Box of Square Cross Section

Method of Solution

An approximate solution has been obtained by considering the strain energies of stretching and bending of the wall plating which would be associated with an assumed mode of buckling. The analysis depends on a set of simplifying assumptions which have been suggested by experiment.

The notation used in this article is given in column 1 on page 692.

Modes of Distortion.—The Bredt-Batho[1] distortion, illustrated in Fig. 1, is assumed as a primary mode. A secondary mode of distortion, having displacement from the primary mode, is assumed as shown in Fig. 2. The panel *ABCD* of Fig. 2 is shown again in Fig. 3(*b*), and the deflections of the secondary mode are expressed as

$$w=(w_o+w_i)\sin\frac{\pi[x-f(y)]}{l}F(y) \quad . \quad . \quad (1)$$

where

w_o = the maximum initial deflection of the plating
w_i = the maximum increment in deflection due to load.

$$f(y)=\alpha y+\beta\frac{b}{\pi}\sin\frac{\pi y}{b},$$

$$F(y)=\cos\frac{\pi y}{b}+\chi\sin^2\frac{\pi y}{b}\cos^2\frac{\pi y}{b}$$

and α, β, χ are parameters defining the waveform.

It may be noted from the form of equation (1) that the corners of a box would remain helical, and experiments show this to be reasonable within elastic ranges of loading.

Mid-Plate Stresses.—Experimental evidence obtained by Sparkes, Chapman and

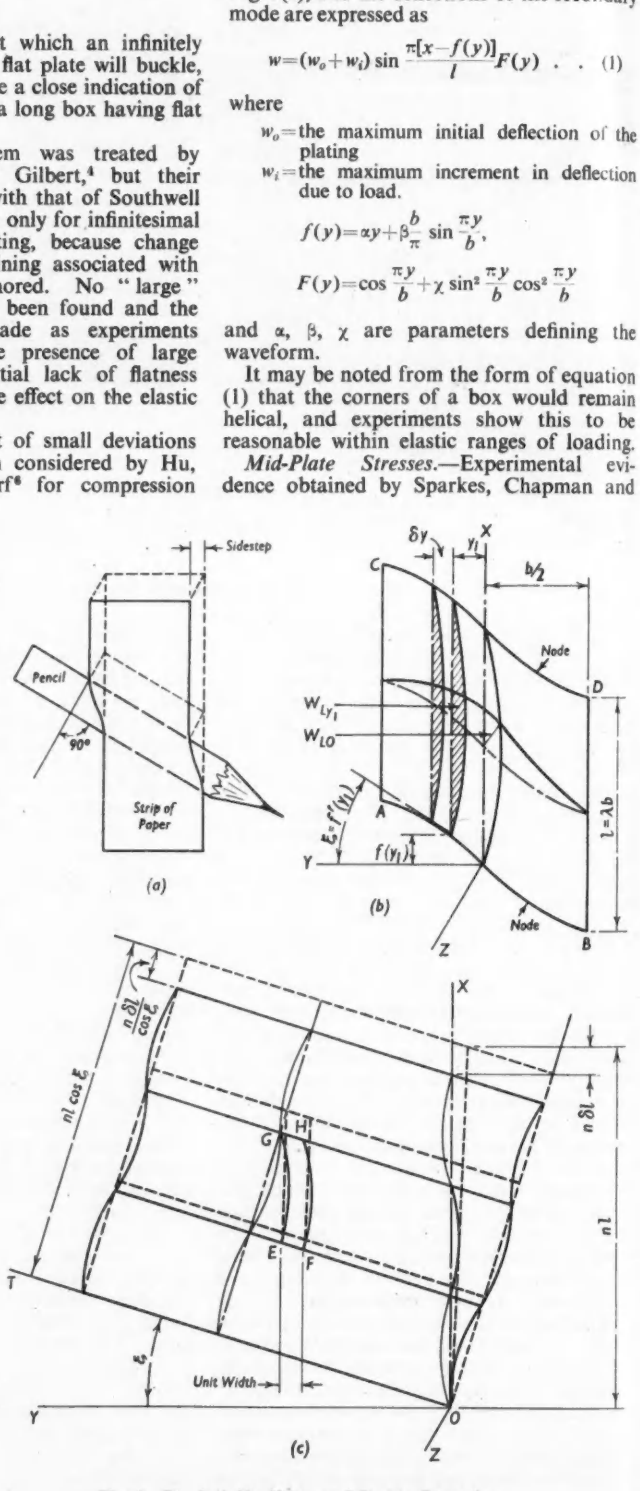


Fig. 3—Physical Significance of Buckle Formation

Pippard[9], by Li[9], and by van der Neut[8] indicates that where the plate aspect ratio is about 3 or greater the membrane stress in the buckled plating of a box is practically constant along given laterals and longitudinals.

It is assumed therefore that the longitudinal mean stress σ_x is a function of y only, whilst the transverse stress $\sigma_y=0$.

Then from the equilibrium equations[2] τ_{xy}=a constant.

Physical Significance of Buckling.—A flat plate which buckles under a given shear loading in its own plane, and consequently has certain displacements at its boundaries, must have less stored energy in its buckled form than it would have if it were maintained flat whilst subject to the same displacements at the boundaries.

The buckles provide an opportunity for the median surface longitudinal generators to "sidestep" slightly as they cross over a buckle from start to finish of a wave. The effect may be demonstrated quite simply by placing a pencil on a table and laying a ribbon of paper across it as shown in

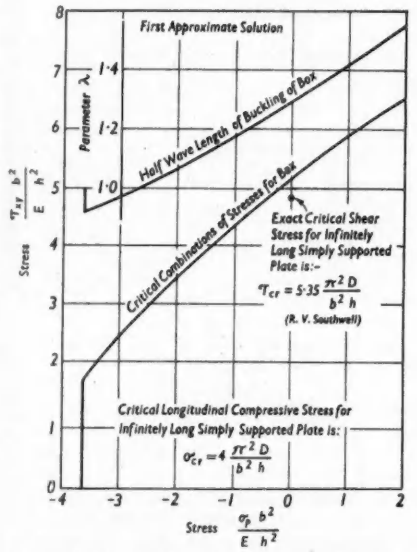

First Approximate Solution
Parameter λ
Half Wave Length of Buckling of Box
Critical Combinations of Stresses for Box
Exact Critical Shear Stress for Infinitely Long Simply Supported Plate is:-
$\tau_{cr}=5{\cdot}35\frac{\pi^2 D}{b^2 h}$
(R. V. Southwell)
Critical Longitudinal Compressive Stress for Infinitely Long Simply Supported Plate is:
$\sigma_{cr}=4\frac{\pi^2 D}{b^2 h}$
Stress $\frac{\tau_{xy}\,b^2}{E\,h^2}$
Stress $\frac{\sigma_p\,b^2}{E\,h^2}$

Fig. 4—Critical Combinations of Shear Stress and Longitudinal Stress for Local Buckling of the Plating of a Thin Walled Box of Square Cross Section Having no Initial Deformations

Fig. 3(*a*). The "sidestep" may be viewed as an assemblage of body rotations and movements of elements of the middle surface.

It is this effect which permits the rotation of a buckled thin-walled box to be greater than would be expected from Hookes Law and the Bredt-Batho theory alone.

From equation (1) it can be shown that the longitudinal mid-plate stress is

$$\sigma_x=\frac{\pi^2}{4}\frac{E}{l^2}(2w_o+w_i)w_i\left[F^2(y)-\frac{1}{b}\int_{-\frac{b}{2}}^{\frac{b}{2}}F^2(y)dy\right] \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

and the mean effective shear strain of the plating is

$$\gamma=\frac{\tau_{xy}}{G}+\frac{\pi^2}{2}\frac{1}{bl^2}(2w_o+w_i)w_i\int_{-\frac{b}{2}}^{\frac{b}{2}}F^2(y)f'(y)dy \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where τ_{xy} is the mean Bredt-Batho shear stress due to torque and G is the shear modulus of the wall plating.

Strain Energy Relationship.—Before the information contained in equations (2) and (3) can be used it is necessary to find the

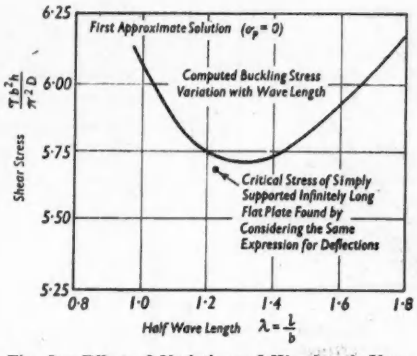

First Approximate Solution ($\sigma_p=0$)
Computed Buckling Stress Variation with Wave Length
Critical Stress of Simply Supported Infinitely Long Flat Plate Found by Considering the Same Expression for Deflections
Shear Stress $\frac{\tau b^2 h}{\pi^2 D}$
Half Wave Length $\lambda=\frac{l}{b}$

Fig. 5a—Effect of Variations of Wavelength Upon Buckling Stress

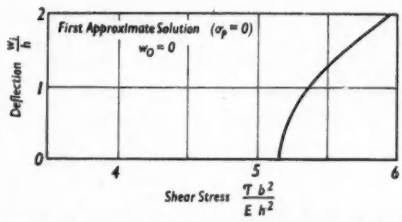


Fig. 5b—Large Displacement Buckling of Plating

values of the parameters l and w_i appropriate to given values of τ_{xy}.

l and w_i can be found from the principle of virtual work,

$$\frac{\partial V}{\partial w_i}dw_i=\frac{\partial(U_S+U_B)}{\partial w_i}dw_i \quad . \quad . \quad . \quad (4)$$

where

V=external work done by τ_{xy}.
U_S=strain energy of stretching of plating.
U_B=strain energy of bending of plating.

Results and Brief Description of Analysis

Physical considerations and an examination of the exact buckle patterns obtained by Southwell and Skan suggested a deflection expression :

$$w=(w_o+w_i)\sin\left(\frac{\pi\left(x-\alpha y-\beta\frac{b}{\pi}\sin\frac{\pi y}{b}\right)}{\lambda b}\right)\left(\cos\frac{\pi y}{b}+\chi\sin^2\frac{\pi y}{b}\cos^2\frac{\pi y}{b}\right) \quad . \quad . \quad . \quad . \quad (5)$$

where $\lambda=l/b$.

When $\beta=\chi=0$ equation (5) is of the form employed by Timoshenko[3] and Figs. 4 and 5 have been obtained for that case in order to give a comparison with previous results. For Fig. 4 an applied compressive stress, σ_P, is considered as a mean stress on a cross section of the box. The curve shows the combinations of shear and compression which would cause critical buckling of the plating. It compares favourably with the results presented by Budiansky, Stein and Gilbert.[4]

Critical Shear Stress.—The nodal lines (lines where there is no deflection due to buckling) must form continuous traces around the box and advance an integral number of wavelengths for each circuit. This statement can be written as

$$\frac{\alpha}{2}+\frac{\beta}{\pi}=\frac{n}{4}\lambda \quad . \quad . \quad . \quad . \quad . \quad (6)$$

where n is an integer.

By substituting equations (5) and (6) in (4) the value of critical shear stress obtained is

$$\frac{(\tau_{xy})_{cr}b^2h}{\pi^2D}=5{\cdot}44 \quad . \quad . \quad . \quad . \quad (7)$$

where the parameters $\alpha=0{\cdot}310$, $\beta=0{\cdot}487$, $\chi=0{\cdot}050$, $\lambda=1{\cdot}24$ have been obtained by a method of successive approximation.

Southwell and Skan's exact solution for the critical shear stress of a long simply supported plate is

$$\frac{(\tau_{xy})_{cr}b^2h}{\pi^2D}=5{\cdot}35.$$

Approximate solutions obtained by Rayleigh's principle over-estimate the magnitude of the required quantity. Therefore, one can write,

$$5{\cdot}35<\left[\frac{(\tau_{xy})_{cr}b^2h}{\pi^2D}\right]_{exact}<5{\cdot}44$$

and conclude that the result which has been obtained is within 2 per cent of the unknown exact critical shear stress for the plating of the box.

Buckling Deflections.—In the solution of equation (4) w_i, α, β, χ and λ appear as parameters which should be determined for given values of w_o and τ_{xy}. This could have been done, but the heavy computation involved would have required more time and effort than was thought to be warranted.

However, by assuming that the plating buckles in the form it would adopt at the critical shear stress a very great simplification results. τ_{xy} may then be expressed directly in terms of w_o and w_i as

$$\tau_{xy}=E\frac{h^2}{b^2}\left[0{\cdot}274\left(\frac{2w_o}{h}+\frac{w_i}{h}\right)\frac{w_i}{h}+4{\cdot}92\frac{w_i}{w_o+w_i}\right]$$

or

$$\frac{\tau_{xy}b^2}{Eh^2}=0{\cdot}274\left(\frac{2w_o}{h}+\frac{w_i}{h}\right)\frac{w_i}{h}+4{\cdot}92\frac{w_i}{w_o+w_i} \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

where ν has been taken as 0·3.

Computations based on equation (8) are shown in Fig. 6.

Membrane Strains and Stresses.—By substituting equation (5) in (2) and using the values of α, β, χ, and λ appropriate to the critical stress, the longitudinal membrane

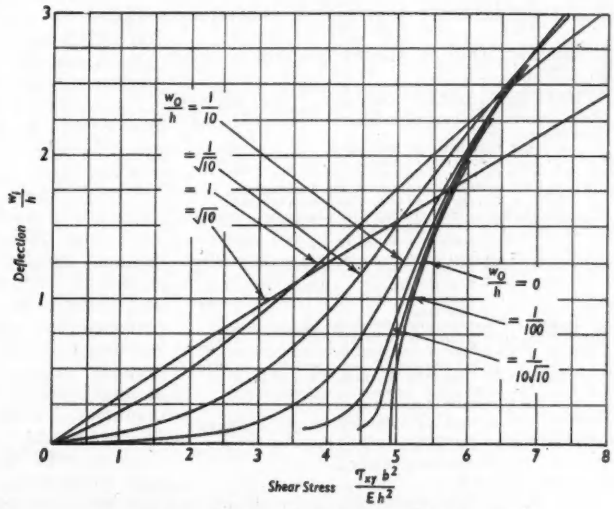


Fig. 6—Large Displacement Buckling of Plating

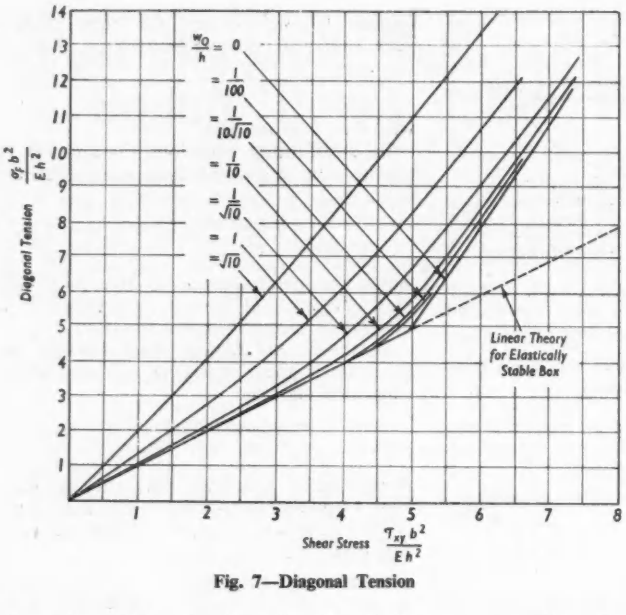


Fig. 7—Diagonal Tension

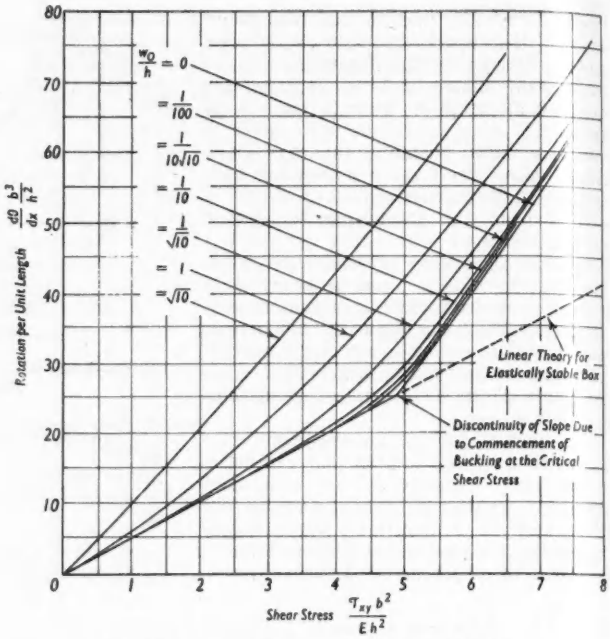


Fig. 8—Effect of Buckling Upon Torsional Rigidity

stress along the centre line of a side of the box becomes :

$$\left\{\frac{\sigma_x b^2}{Eh^2}\right\}_{y=0} = 0{\cdot}79\left(\frac{2w_o}{h}+\frac{w_i}{h}\right)\frac{w_i}{h} \quad . \quad . \quad (9a)$$

and the membrane stress along the corners is then

$$\left\{\frac{\sigma_x b^2}{Eh^2}\right\}_{y=\pm\frac{b}{2}} = -0{\cdot}81\left(\frac{2w_o}{h}+\frac{w_i}{h}\right)\frac{w_i}{h} \quad . \quad . \quad (9b)$$

It is of interest to note from these equations that for large deflections σ_x can be of the same order of magnitude as the shear stress due to torque ; yet it is zero for a box having flat plating until the torque exceeds its critical magnitude. Using a mean magnitude coefficient of 0·80 equations (9) are shown graphically in Fig. 9.

Torsional Rigidity.—By geometry it can be seen from Fig. 1 that the rate of twist of a box is $d\theta/dx = 2/b \,.\, \gamma$ where γ is the mean overall shear strain. By substituting for γ from the results of the theory one obtains

$$\frac{b^3}{h^2}\frac{d\theta}{dx} = 5{\cdot}20\left[\frac{\tau_{xy}b^2}{Eh^2}+0{\cdot}453\left(\frac{2w_o}{h}+\frac{w_i}{h}\right)\frac{w_i}{h}\right] \quad . \quad . \quad . \quad . \quad (10)$$

Some computations based on equation (10) are shown in Fig. 8.

Diagonal Tension.—The maximum mid-plate direct stress parallel to a nodal line trace occurs along the centre lines of a side of the box and is given, approximately, by

$$\frac{\sigma_p b^2}{Eh^2} = \frac{\tau_{xy}b^2}{Eh^2}+0{\cdot}612\,\frac{\sigma_x b^2}{Eh^2} \quad . \quad . \quad (11)$$

Equation (11) is shown graphically in Fig. 7.

Maximum Surface Stresses.—The maximum surface direct stresses, at right angles to an anti-nodal line trace, occur on the plate at the junctions of the anti-nodal lines and the centre lines of the sides of the box. These stresses are given, approximately, by

$$\frac{\sigma_p b^2}{Eh^2} = -\frac{\tau_{xy}b^2}{Eh^2}+0{\cdot}612\,\frac{\sigma_x b^2}{Eh^2} \pm 6{\cdot}72\,\frac{w_i}{h} \quad . \quad (12)$$

This is shown graphically in Fig. 10.

Discussion of Theoretical Results

From Fig. 6 it can be seen that for plates having initial deformations, however small, buckling will occur from the first applications of load. The concept of critical stress thus has meaning only for perfectly flat plating and in all engineering structures having thin plating buckling will occur as soon as load is applied. However, the stage at which the buckles become significant is related to both the quality of manufacture and the true critical stress of flat plating.

From Fig. 9 is can be seen that "secondary" stresses are dependent on both the initial deflections and the deflections due to load and that when the deflection of a plate is of the order of twice the plate thickness the secondary stresses are of the same order as the primary stress.

Fig. 8 shows the influence of buckling upon the angle of twist of a box.

Fig. 7 shows the influence of buckling upon the mid-plate diagonal tension. In both Figs. 7 and 8 the post critical line for perfectly flat plating is straight. This is because it has been assumed that the plate continues to buckle in the critical mode. It is believed that if this restriction had not been introduced for ease of computa-

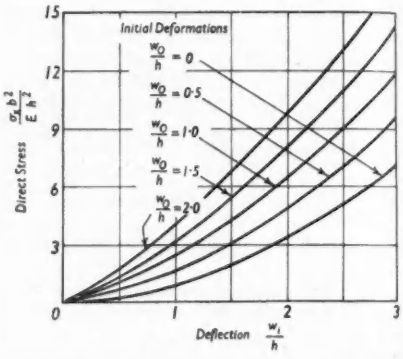


Fig. 9—Maximum Longitudinal Direct Membrane Stress Due to Buckling

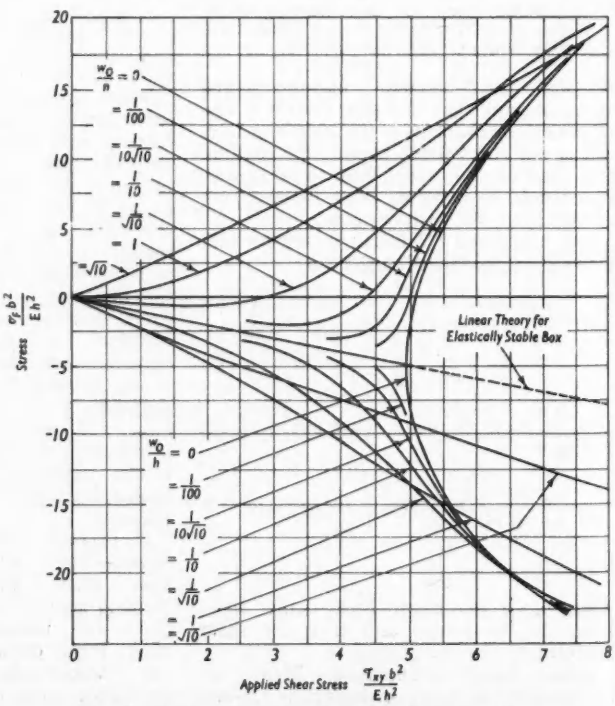


Fig. 10—Development of Maximum Surface Stresses

Notation :

x, y, z—rectangular co-ordinates.
h—thickness of plating.
b—width of side of box.
θ—relative rotation between diaphragms.
σ, τ—normal and shear components of stress.
σ_x, σ_y—normal components of stresses parallel to x, y, directions.
σ_p—maximum direct stress.
τ_{xy}—shear components of stress for co-ordinates x, y.
ν—Poisson's ratio.
E—modulus of elasticity in tension or compression.
$G = E/2(1+\nu)$—modulus of elasticity in shear.
$D = Eh^3/12(1-\nu^2)$—flexural rigidity of a plate.
w—deflection of a plate from plane OXY.
l—half wavelength of buckling, measured parallel to longitudinal axis of box.
$\lambda = l/b$—parameter representing wavelength.
ξ—Inclination of nodal line to y axis.
γ—Total mean effective shear strain of a buckled plate.
P—A direct force per unit length of perimeter applied at ends of box.
$\sigma_p = p/h$.
U_S, U_B—Strain energy of stretching and bending.
V—external work.

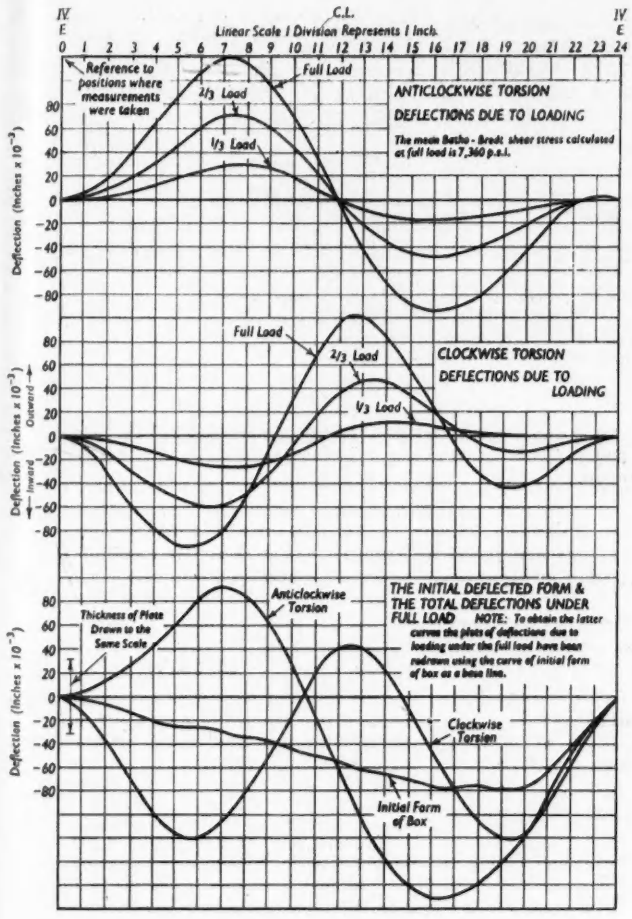

Linear Scale 1 Division Represents 1 Inch.
Reference to positions where measurements were taken
Full Load
2/3 Load
1/3 Load
ANTICLOCKWISE TORSION
DEFLECTIONS DUE TO LOADING
The mean Batho - Bredt shear stress calculated at full load is 7,360 p.s.i.
CLOCKWISE TORSION
DEFLECTIONS DUE TO LOADING
Deflection (Inches x 10⁻³)
Outward
Inward
Thickness of Plate Drawn to the Same Scale
Anticlockwise Torsion
Clockwise Torsion
Initial Form of Box
THE INITIAL DEFLECTED FORM & THE TOTAL DEFLECTIONS UNDER FULL LOAD NOTE: To obtain the latter curves the plots of deflections due to loading under the full load have been redrawn using the curve of initial form of box as a base line.

Fig. 11—Box No. II : Deflections Measured at Stations Along the Longitudinal Centre Line of Side No. IV

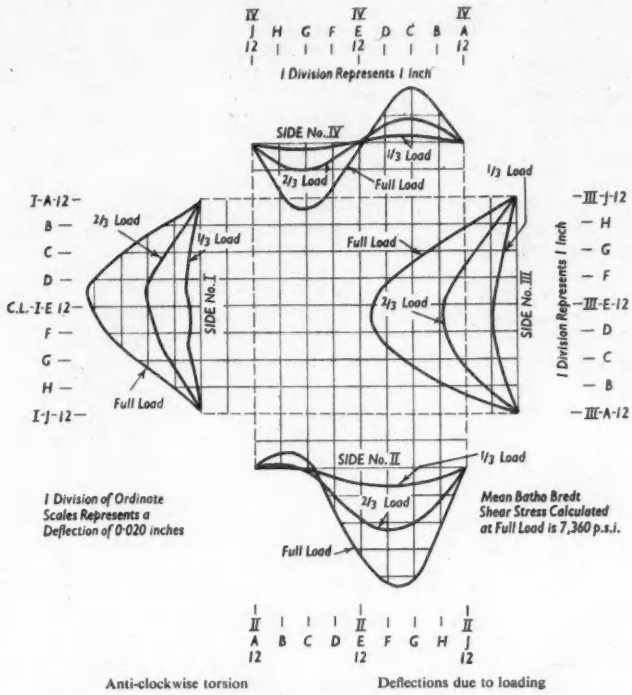

1 Division Represents 1 Inch
SIDE No. IV
SIDE No. I
SIDE No. III
SIDE No. II
1/3 Load
2/3 Load
Full Load
1 Division of Ordinate Scales Represents a Deflection of 0·020 inches
Mean Batho Bredt Shear Stress Calculated at Full Load is 7,360 p.s.i.
Anti-clockwise torsion
Deflections due to loading

Fig. 12—Box No. II : Deflections Measured at Stations Around the Centre Cross Section

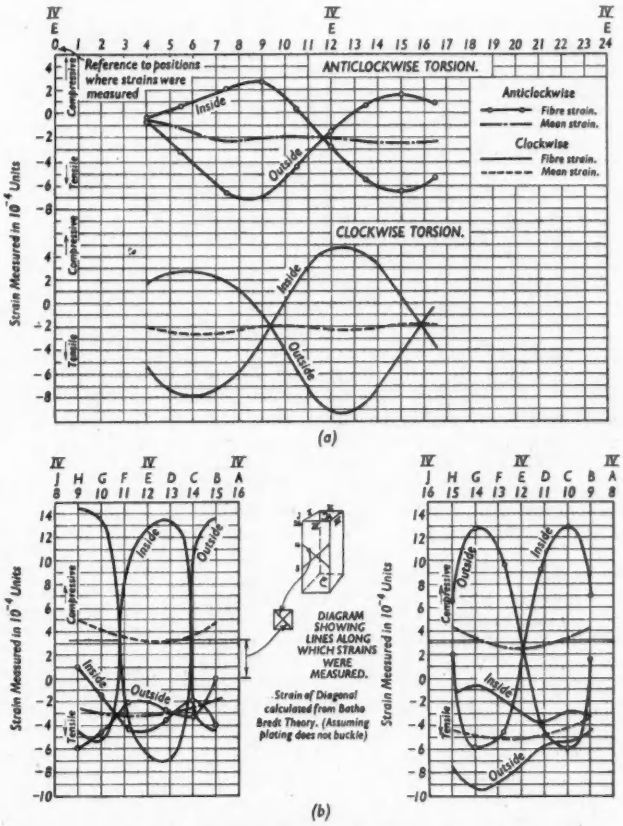


Fig. 13 (a)—Box No. II : Distribution of Axial Strain on Longitudinal Centre Line of Side No. IV

Fig. 13 (b)—Box No. II : Distribution of Strain on Sections at 45 deg. to the Longitudinal Centre Line of Side No. IV

tion the lines would be slightly curved.

Fig. 10 shows the greatest deviations from linearity of behaviour predicted by the theory. If the initial buckles are between one-third and the full plate thickness, one surface stress in the direction of diagonal compression may never be compressive, but only tensile from the first application of load. If the material of a box having $w_o/h<1$ has a yield stress $\sigma b^2/Eh^2>20$ then the critical load for a perfectly formed box may be applied without yielding the plating. However, the material of a box having $w_o/h=1$ and a yield stress $\sigma b^2/Eh^2=5$ will yield when the applied load reaches about 50 per cent of the critical load.

It can also be seen from Fig. 10 that for efficient use of material the yield stress should be appreciably higher than the buckling stress. This fact has been noted in previous experiments[10] on flat plates.

Experimental Determination of Critical Stresses

It appears to the author that more emphasis than appears warranted has been placed upon a knowledge of buckling stresses alone. The influence of initial deformations seems to have been largely ignored. Yet experiments designed to measure critical buckling stresses have shown the influence of the initial deformations. So pronounced can the influence be that experimenters usually have difficulty in stating the " buckling stresses."

Many devices[10] have been employed for the determination of the true critical stresses such as the method of " Southwell plots," noting the " top-of-the-knee " in the load deflection diagrams, and noting the " strain reversals " in electric strain gauge readings. The theoretical curves indicate that these are unsatisfactory for all except extremely well-made plates. The method of " strain reversal " is the least satisfactory, and when the initial deflections are of the order of the plate thickness may give zero for the " critical " stress.

Inspection of Figs. 6 and 10 shows that closer indications of true critical stress may be had by noting the points of inflexion of the load deflection curves, and of the load maximum - surface - diagonal - compressive stress curves. Both these methods could give good indications for plating having initial deformation less than one-tenth of its thickness. Part confirmation of this load-deflection - inflexion - point method has been found in a publication by Coan.[11]

Certain practical difficulties occur in using all these methods. For example, it is difficult to predict the location of buckle crests and their location may not remain fixed.

Comparison with Experiment

Figs. 11 to 14 have been extracted from an unpublished report by the author, and show results obtained for pure torsion of an unstiffened welded mild steel box 24in long between diaphragms, and 8in square in internal cross section, having walls 0·06in thick. The tube was constructed by welding four flat plates along the corner junctions, and although the appearance of the welding was good the initial buckle amplitudes were, nevertheless, irregular and of the same order as the plate thickness.

The test results have been obtained for a

range of Bredt-Batho shear stress of 0–7360 p.s.i., in which the box was within the theoretical critical stress of 8510 p.s.i. Sudden failure occurred subsequently at an applied shear stress of 10,100 p.s.i.

Fig. 11 shows deflections on the longitudinal centre line of a side. These have increased approximately linearly with load and have reached maximum amplitudes of about twice the plate thickness which is in good agreement with the curve for $w_o/h=1$ in Fig. 6.

Fig. 14 shows maximum deviations in twist from elementary theory of the order of 50 per cent, as predicted by the curve for $w_o/h=1$ of Fig. 8. Fig. 12 shows the essential

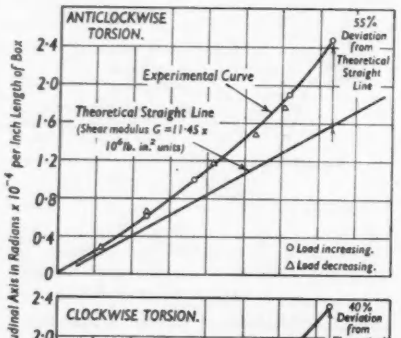


Fig. 14—Box No. II : Angular Rotation for Torsional Loading within Elastic Region

conformity of buckling patterns in adjacent sides and has similarity to Section 2–2 of Fig. 2. Finally, Fig. 13 gives surface and mid-plate strains and is reasonably consistent with the assumption that σ_x is a function of y.

Within the range of elastic behaviour the corner lines showed negligible distortion from helical form, thus giving justification for the assumed secondary mode of distortion.

Conclusions

From the theory of Bredt and Batho it may have been expected that the rotation of thin-walled unstiffened box girders would vary linearly with applied torque until the loadings reached the critical values for theoretical buckling of the plate material. It has been shown in the present analysis, however, that large deviations from linearity of behaviour may be found well below the critical loadings.

The concept of critical stress buckling has meaning only for plating with perfect initial form. Where there are initial deformations in shape, however small—as there must be in all engineering structures—buckling of plating will occur from the first applications of load. The development of the buckling is greatly influenced by the magnitude of the initial deformations.

A study of Figs. 6, 7, 8, 9 and 10 should give a good impression of the non-linear behaviour to be anticipated from the present theory.

For efficient use of material the yield stress should be appreciably higher than the buckling stress. The required ratio is dependent on the initial deformations and on the non-dimensional yield stress. A flat plate having an initial deflection one-tenth of its thickness and a yield stress equal to the buckling stress would be expected to yield at three-quarters of the critical loading.

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B.I.S.R.A. Laboratories at Sheffield

The work of the British Iron and Steel Research Association particularly concerned with the making, working and metallurgy of steel is now concentrated in new laboratories opened last week at Sheffield. They constitute a miniature steelworks equipped with pilot plant with which it is hoped to bridge the gap between the laboratory and the industry. The major items of equipment are described below.

An event of particular significance in the organisation of iron and steel research work in Great Britain took place on Thursday, November 19th, when H.R.H. The Duke of Edinburgh formally opened the laboratories which have been established by the British Iron and Steel Research Association at Sheffield. On this site will be undertaken those aspects of the Association's research on the making, working and metallurgy of steel. The establishment has so far cost £500,000, and is, in fact, a miniature steelworks housing pilot machinery for the melting, rolling, drawing and forging of steel. Hence, in these laboratories, new sub-scale plant can be developed and tried out before it is committed to full-scale manufacture, thereby reducing the risks of rejection or modification at this stage. New methods and processes suggested by the Association's work here, and at its other research establishments, can also be more accurately assessed by the extensive control and instrumentation equipment provided than they could on industrial plant. An object of equal importance is the investigation of other time-honoured techniques and safety factors of steelworking which, though long practised and recognised by the craftsman, are based on many factors still little understood. It is hoped thereby with this establishment to reduce the gap between the laboratory and the steelworks which has hitherto been a handicap to progress.

The laboratories consist of four new and three older buildings. The three new laboratories are : main block (three storeys totalling approximately 30,000 square feet floor area), the metal working shop (10,000 square feet), the melting shop (4000 square feet). The other buildings are the cutlery laboratory (formerly the offices of Daniel Doncaster and Sons, Ltd.), the machine shop, the furnace model room, and the annexe (a temporary building erected in 1948). Some of the constructional details are not without interest, and are included here before passing to a description of the more important items of equipment.

The main block contains laboratories and work rooms, administrative offices, and extensions can be arranged at either end and provisions made for the addition of another storey to the building. All internal walls and partitions can be easily removed and new layouts built up.

The principal services—electricity, gas, heating and air conditioning, water and drainage—are laid in a comprehensive and accessible system of ducts which is carried to every working room in the building. This system allows work rooms and offices to be converted into laboratories and vice versa without interfering with the structure of the building. Each corridor has a false ceiling which forms a horizontal duct running its full length and width. Into this duct the services are led from vertical ducts. Access is obtained via removable ceiling panels. Secondary ducts branch off at right angles to the corridor beneath the floors of the adjacent rooms and are accessible through removable panels in the ceilings of the rooms below. From these, tertiary ducts branch off parallel to the corridors to complete the pattern of distribution.

A particularly interesting advantage of this system is that the loss of floor space due to the ducting is less than 1 per cent of the whole, while the utilisation of wall space in the laboratories is entirely unaffected. Also of interest is the portal arch construction, the advantages of which can be noted in several of our illustrations.

The metal working shop, shown in Fig. 1 and 2 houses a strip rolling mill, a wire drawing machine and a forging press, all of industrial size, as well as various smaller pieces of equipment. It is a single-storey building using steel portal frames with brick walls, a concrete floor, and large hollow glass-brick panels.

It is worth noting that the mill motor-generator set is cooled by forcing cold air from a small pressurised basement through holes in its foundation and into the machines. The warmed air then exhausts into the motor generator room and escapes into the main duct system, thus combating dampness in the tunnels. Although the main block adjoins the metal working shop, its foundations and structure are completely separate so as to minimise the transmission of vibration from the heavy plant in the metal working shop.

The melting shop consists of a single-storey, steel-framed main shop and a two-storey brick building adjoining. The ground floor of the adjoining building houses the station compressed air plant, arc furnace transformer and its associated switchgear and controls. The first floor houses a small laboratory and an emergency water tank, which is part of the water system to the arc furnace. The new laboratories were begun in August, 1950, with Messrs. Husband and Co. acting as consulting engineers and architects, and George Longden and Co., Ltd., as chief contractors. Of the total cost £200,000 was expended on equipment.

Research at the Sheffield Laboratories is organised within three divisions concerned with steel-making, metal working and metallurgy. The steel-making laboratory is particularly concerned with the processes in the open-hearth and electric furnaces and with the casting of ingots. The metal working laboratory studies the processes from the ingot to the finished product whether it be plate, sheet, sections, wire or forgings. The metallurgy laboratory is concerned with the behaviour of steel, for example, under heat-treatment, and with special steels. It includes an analytical chemistry laboratory. The cutlery laboratory is separately organised and sponsored by the Cutlery Research Council, but is substantially integrated with the other laboratories.

Main Equipment

Electric Arc Furnace.—The principal item of equipment in the melting shop is the 10 cwt

arc furnace. It was supplied by the Electric Furnace Company, Ltd., and is generally of conventional Heroult design, but it incorporates a number of special details which widen the range over which research can be conducted. The shell is 5ft in diameter and the height of the walls can be varied from 1ft 5in to 2ft 2in (sill to roof ring) by the inclusion of separate sections. Graphite electrodes, 4in in diameter, are in use at present, on a 12in diameter pitch circle, and provision has been made for the variation of the pitch circle up to the full diameter of the bath and for the use of 7in diameter electrodes. Research will also be done on Soderberg electrodes and on other alternatives to graphite. Silica brick has normally been used in the roof and, so far, chrome magnesite for the walls. The furnace bottom is of austenitic (non-magnetic) steel in order that induction stirring equipment can be fitted at a later date, if required. A specially high maximum forward tilt of 60 deg. is provided, with 15 deg. reverse tilt.

The furnace transformer, supplied by the Metropolitan-Vickers Electrical Company, Ltd., is of 500kVA nominal capacity and is larger than would normally be used on a 10 cwt furnace in order that the effects of high-power input rates can be investigated. The work so far carried out with the furnace has been mainly concerned with the effects of a number of variables on power and electrode consumption with the object of reducing operating costs and thus widening the range of steels over which the arc furnace can compete with the open hearth. The greatest effect so far found is that about 20 per cent less energy is required with an input rate of 500kVA than with 250kVA, and that refractory wear or electrode consumption wear is not seriously affected.

Work on refractory wear is now also in progress and the furnace has been arranged so as to facilitate this measurement (Fig. 6). Other kinds of work envisaged are on steel quality and the chemistry of the steel-making process. A further important purpose of the furnace is to provide molten steel for a variety of experiments, mainly on problems in casting.

Rolling Mill.—The rolling mill, shown in Fig. 4, was designed and built by W. H. A. Robertson, Ltd., which sub-contracted the electrical design and construction to the Metropolitan-Vickers Electrical Company, Ltd. It is a high-speed reversible four-high cold strip mill and will accommodate work rolls from 3½in to 7in diameter. The back-up rolls are 14½in diameter and all rolls have a 14in face width. Roll balance and coil ejection is hydraulic, and the wiper and guide table movements are pneumatic. Screwdown is by two 5 h.p. motors, operated independently or together, the total design load being 300 tons. The main mill motor has a maximum continuous output of 750 h.p. and each coiler is equipped with a 200 h.p. motor which enables a wide range of front and back tensions to be applied. The coiler drums will take a 4-ton, 56in diameter, 12in wide coil. Provision is made to convert the mill into a two-high machine with 14½in diameter rolls if required in the future.

In order to allow as wide a field of cold rolling research as possible to be undertaken, operating conditions have been extended far beyond the normal production limits. The speed of the main motor can be varied from zero to 955 r.p.m., giving an ingoing strip speed of 0ft to 1750ft per minute with 7in diameter rolls. Any given speed can be preset and repeated accurately within these limits, irrespective of load. The acceleration from zero to maximum speed can be preset between 10 and 30 seconds. Back and front tensions can be applied, and for a given setting are kept constant during acceleration, deceleration and change in coil diameter. Under normal running conditions the maximum tension available is 2 tons per side, but there is a control which will increase this by any factor up to 100 per cent. Under stalled conditions the tension is automatically reduced, but by pressing a button the running tension can be obtained for short periods. It is also possible to reel strip from one coiler to the other under full tension control with the rolls lifted.

The coiler motors are each fed from their own generator, and controlled by metadynes. Apart from controlling tensions under the conditions mentioned, the metadynes provide for draught adjustment up to 90 per cent, inching each coiler independently or with the mill, adjusting speeds when different diameter work rolls are fitted, and also prevent the motors overspeeding if the strip breaks. At speeds below 200ft per minute the mill is controlled from a separate metadyne system which obtains a signal from a belt-driven tachogenerator on the mill motor extension shaft.

The control desk is divided into three sections. To the operator's right side there are the coiler motor and tension controls. On the left are screwdown controls and grouped in the middle are the master switch and subsidiary running controls. For normal running, the preset speed control handwheel is set to the required value, the acceleration rate set as required, then the mill is started and controlled by the master switch.

The roll force, back and front tensions and strip gauge are measured by means of instruments designed and built in the B.I.S.R.A. laboratories and displayed on the mill housing in front of the operator. Repeater meters are mounted in a cabinet so that a continuous photographic record can be obtained if required. The mill is also equipped for research on several systems of automatic gauge control. One method developed by B.I.S.R.A. during the last few years has already operated successfully for some months in the works of a member firm. The importance of gauge control is shown by the fact that with the methods normally in use at present up to 8 or 10 per cent of the strip made in a modern high-speed strip mill may be off-gauge.

The Forging Press.—The press, which was originally built in 1939 by the Hydraulic Engineering Company, is a vertical down-stroke hydraulic machine (Fig. 5) of 200 tons capacity, the load being applied by a double-acting, piston ram 10in by 10¼in diameter with a stroke of 15in. The working tables measure 25in by 31in and the maximum daylight between platens is 26in.

As the machine is used for general research into forging problems, it has to be capable of providing widely varying speeds and loads. The maximum load can be set anywhere between the limits 4 to 200 tons and repeated with an accuracy of ±2½ per cent. Within the range 0 to 100 tons load (equivalent to 0 lb to 2500 lb per square inch oil pressure) the ram speed is infinitely variable between 0·03in per second and 3·09in per second. Under heavier loading the maximum ram speed is reduced, giving limits of 0·3in to 1·54in per second. Automatic prefilling is provided and a ram return speed of 2·85in per second is obtained.

In order to provide for the wide range of speeds and pressures required, the new Towler "Electraulic" pumping and control gear is used. The pumping equipment, which can be seen in Fig. 5, consists of four high-speed units, each comprising two "in line" plunger pumps and a 25 h.p. driving motor, together with a smaller high-speed axial plunger pump driven by a 4 h.p. motor. Oil is used as the pressure fluid in a completely closed circuit, the main storage tank being on top of the press. The five pump motors are controlled by a ten-way push-button station on the control panel, which provides a "stop" and "start" button for each individual motor. Next to this is a seven-way station giving "close," "open" and "stop" control on the ram and "in" and "out" control on each of two solenoid operated by-pass valves. Also on the control panel is a pressure gauge calibrated in pounds per square inch oil pressure, and a knob controlling a metering valve which enables any desired part of the 2000 cubic inches per minute delivery of one pump to be by-passed to exhaust. On top of the cabinet is a calibrated thimble control for the variable-pressure relief and unloading valve.

Fig. 1—Main Building and Metal Working Shop

The pressing speed required is obtained by starting a selected number of the main pumps and obtaining a fine adjustment by exhausting part of the output of one pump. The variable-pressure relief valve is set at the required pressure, then the press can be operated by the "close," "stop" and "open" buttons. When the ram is stopped, pressure is maintained in the cylinder by the pilot pump. Limit switches are fitted to enable any stroke to be repeated simply by operating the "open" and "close" buttons.

The Wire-Drawing Machine.—The achievement of higher drawing speeds is the primary object of investigations on this installation, and here problems of die lubrication form an important aspect of the work. In connection with this task a technique has been devised for measuring dielectrically the thickness of the film of lubricant on the wire when passing through the die. The machine and its control console is shown in Fig. 3.

It was designed and built by the Marshall Richards Machine Company, Ltd., to B.I.S.R.A. specification. It is a two-hole, straight-line machine with a spool feed and take-up, and with 18in diameter capstans mounted on vertical shafts coupled directly to the driving motors. Interchangeable drawing sleeves are provided

B.I.S.R.A. LABORATORIES, SHEFFIELD

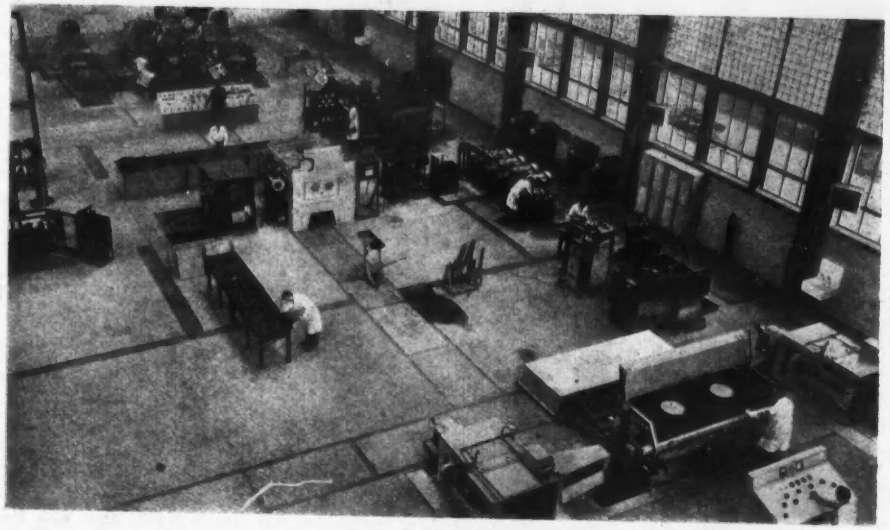

Fig. 2—Metal Working Shop

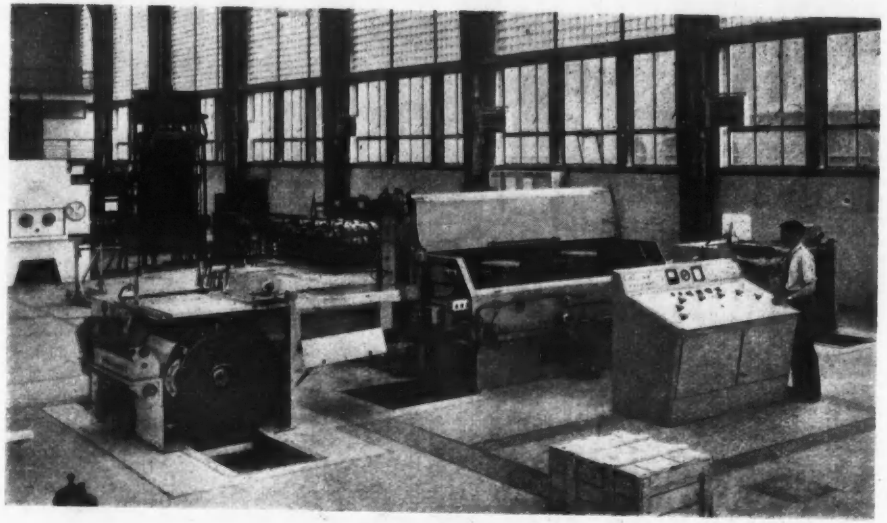

Fig. 3—Wire Drawing Machine

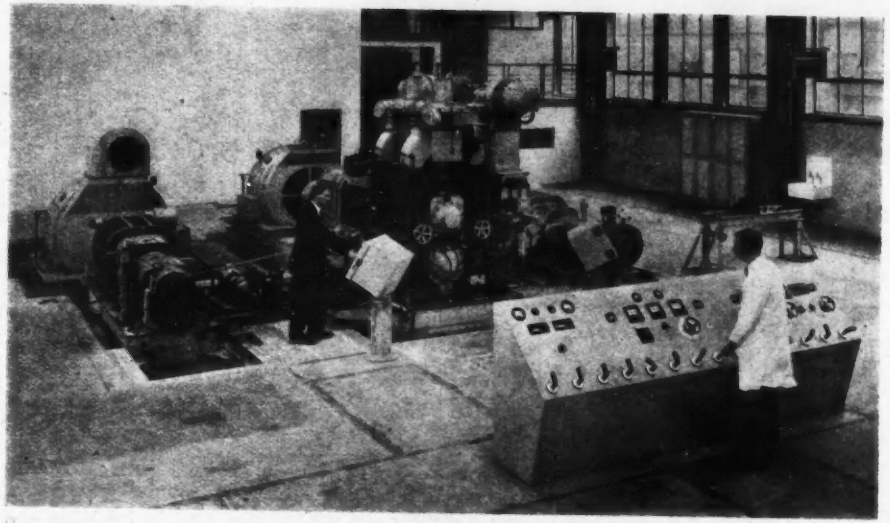

Fig. 4—Rolling Mill

Fig. 5—Forging Press

for the capstans, allowing for the number of wire laps to be varied up to 3in in height, without affecting the straight lead out from the dies. Capstans and dies (Fig. 7) are water cooled from a constant pressure supply obtained by passing mains water through a special reducing valve. It is possible to submerge the whole of the drawing compartment in lubricant, circulating it in a closed system or to spray the capstans, dies and wire, the temperature of the lubricant being thermostatically controlled. Alternatively, soap boxes may be fitted for dry drawing. The feed and take-up spools are motor driven and can be either 36in or 42in diameter, to carry approximately 1 ton or 2 tons of wire, respectively. The feed spool mechanism can be used at low speeds to make up spools from coils of wire, and a capstan can be substituted for the take-up spool for coiling.

The machine can be used to draw both ferrous and non-ferrous wire of an initial diameter between 0·040in and 0·104in under widely varying conditions. Drawing can be wet or dry, under temperatures ranging from approximately 10 deg. to 130 deg. Cent. with an area reduction per pass from 0 to 45 per cent. Interpass and spool tensions can be varied from zero to the breaking point of the wire. It can also be run as a slip machine, in which case the capstan motors are linked by interchangeable pulleys and belts, or as a single holer with the first die removed and the first capstan acting as a brake. The maximum inlet speed is 2500ft per minute and in an emergency it is possible to stop the full feed spool from this speed in two seconds under a combination of dynamic braking and twin electromagnetic brakes. The maximum finishing speed is 5000ft per minute.

In order to obtain the wide range of speed required, the d.c. motors driving the capstans

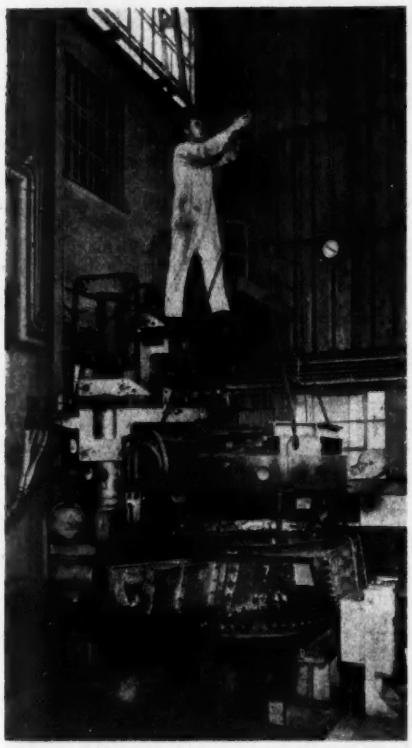

Fig. 6—Weighing the Roof of Electric Arc Furnace

and spools are supplied with current from a grid-controlled mercury arc rectifier by means of which a continuous variation of armature voltage can be obtained, giving continuous speed variation. At high speed control is by a rheostat in the motor field circuit. By this system of control a constant torque is obtained from zero to a speed of approximately 3½ r.p.m. per volt on the armature. The capstan motors are rated at 55 h.p. and the spool motors at 20 h.p., both at 1000 r.p.m. The whole plant is automatically shut down if any motor over-speeds, or passes maximum voltage or current, or if the wire breaks.

The main controls are on a desk facing the machine. They include start and stop controls for the whole of the plant, speed control of the entire plant, acceleration and deceleration rate adjustments for capstan and spool torques. There is also a switch to allow the machine to operate without the lubricant system running. On the machine are controls for independent capstan inching, coarse adjustment of torque,

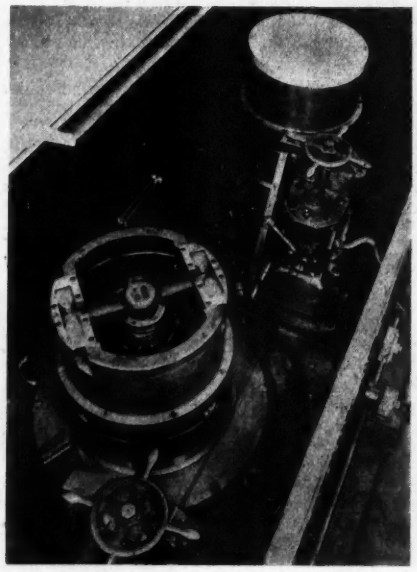

Fig. 7—Detail of Capstans and Dies

speed control and control of water and lubricant temperature and flow. A comprehensive range of instruments which gives full details of the machine's performance is mounted on a separate panel and can be recorded photographically.

High-Vacuum, High-Frequency Melting and Casting Set.—An induction, high-vacuum melting and casting equipment (Fig. 8) has been supplied by Geraetebau-Anstalt Balzers, of Liechtenstein. It comprises a V.S.G. 25 high-vacuum melting and casting set capable of dealing with 55 lb of iron, and an open-air furnace suitable for melting 100 lb of iron. Both furnaces are induction heated and are fed from a common high-frequency (10,000 c/s) vertical spindle A.E.G. motor generator of 110kW rating.

The special characteristic of the apparatus is the melting and casting within the vacuum. It embodies a fixed, double-walled, water-cooled container of stainless steel, volume 18½ cubic feet, with a rotatable coaxial high-frequency lead-through which forms a carrier for the induction coil. The hinged water-cooled lid seats on a rubber gasket and is fitted with a quartz glass observation window and a large vacuum-tight storage chamber with six compartments for containing metals or alloys to be added during the course of the melt. If required, as much as 40 lb of materials can be added to the melt within the high vacuum.

The high-vacuum pumping set includes a two-stage rotary backing pump, a three-stage diffusion pump with a baffle, a backing pump reservoir and a well-designed valve assembly unit. An additional gas inlet valve and an indicating pressure gauge is provided on the valve block so that the melting process can be carried out also in an inert gas atmosphere, if necessary under reduced pressure. The exhausting cross section of the high-vacuum connection is nearly 10in diameter, thus enabling low ultimate pressures to be obtained. Typical pumping times in the cold are from 180mm to 0·1mm of mercury in 2·5 minutes to 10^{-3}mm mercury in 3 minutes, and to 3×10^{-5}mm mercury in 30 minutes. With hot metal it is claimed that 10^{-4}mm mercury can be obtained.

Casting in high vacuum is accomplished by tilting the induction coil containing the melting crucible and pouring the molten metal into a fixed mould supported on an adjustable stainless steel base-plate. Facilities are available for either heating or cooling the mould.

The set is to be used for several purposes, including production of metals and alloys of very high purity, free from gas; application of special casting processes; vacuum distillation of metals; vacuum sintering. Considerable work is in progress on the effects of trace elements, particularly nitrogen, on the efficiency of steel sheet used for transformer cores.

Vacuum Fusion Gas Analysis Apparatus.—An apparatus for the vacuum fusion of gases has been designed to overcome some of the limitations experienced by earlier users of the vacuum fusion method. It is manufactured by W. Edwards and Co., Ltd.

A solid sample is introduced into a graphite crucible in an evacuated system at an elevated temperature of the order of 1700 deg. Cent. at 10^{-6}mm Hg. Under these conditions the oxides are reduced by carbon to carbon monoxide, the nitrides dissociate and hydrogen is also liberated. Heating of the crucible and specimen is carried out by high-frequency induction, using a Phillips high-frequency generator, having an output of 6kW at a frequency of 350 kc/s.

Since the reduction of oxides by carbon is an equilibrium reaction, it is necessary to remove the products of reaction rapidly to ensure completion of the reaction. For this purpose a high-speed mercury vapour diffusion pump is employed. If the efficiency of the pump is not to be impeded by the pressure of gases collecting on the backing side, it must be capable of operating against high backing pressures. The pump is a four-stage pump capable of pumping at a rate of 75 litres per second against high backing pressures, with only moderate heater input. Limiting backing pressure is 35mm Hg and heater capacity 850W. The gases are collected in a Toepler pump, whence they are transferred to a suitable gas analysis apparatus. The dead space to Toepler pump ratio is greater than 10 : 1. The specimen is introduced through a greaseless vacuum lock on the left of the metal header. Thus it is introduced into a readily pumped vacuum system instead of being stored under vacuum conditions for lengthy periods before analysis.

Fatigue Testing Machines.—Twelve orthodox fatigue testing machines have been installed.

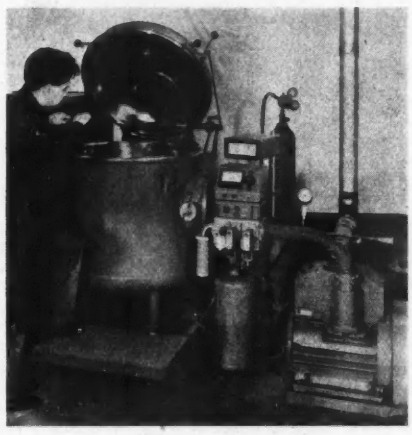

Fig. 8—Vacuum Induction Melting Furnace

The machines can operate at rates up to 5000 r.p.m.

Laboratories.—In the many smaller laboratories a great number of other researches are being conducted using to a large extent conventional methods and equipment. In one, however, we noticed the use of "Plasticine" models, these being built up of coloured laminated strips of this material and then deformed. The association has for some time now been investigating the plastic behaviour of metals with this technique and it maintains that the three-dimensional deformation patterns obtained with "Plasticine" models corresponds very closely to those occurring in metal during hot working.

Automotive Two-Stroke Loop Scavenged Diesel Engines

The capacity of the diesel engine to operate on cheaper fuels has favoured its development in recent years as a unit suitable for light road transport vehicles. This trend has so far been largely pioneered in Germany by Mercedes-Benz and latterly by Fiat in Italy and Citroen in France. Its development in this country is now known to be in hand by several manufacturers, and the range of loop scavenged engines referred to below are based on an Austrian design and made under licence by the Turner Manufacturing Company, Ltd., Wolverhampton.

IN the course of a recent visit to the works of the Turner Manufacturing Company, Ltd., at Wolverhampton, we were shown an automotive two-stroke, two-cylinder diesel engine for which production under licence was shortly to commence. It is one of a range of engines with this cycle and employing a loop scavenging system which have been designed under the direction of Professor H. List for the Anstalt für Motorenbau und Konstruktionen, Vaduz, Liechtenstein. The two-cylinder engine is specifically intended for pleasure cars, taxis and light vans, whilst the three-cylinder in-line, the four-cylinder vee, and the six-cylinder vee engines, which complete the range, have been designed for heavier road transport vehicles and for industrial purposes. The two-cylinder engines, which we saw demonstrated (Figs. 1 and 2), were imported

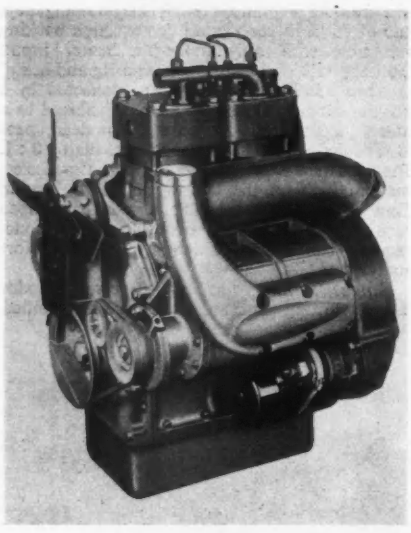

Fig. 1—Two-Cylinder Two-Stroke Loop Scavenged Engine

units and were arranged for inspection in a Vauxhall "Wyvern" and a "Land Rover," in which they have been undergoing road tests. The performance characteristics given in Fig. 3 relate to a 100-hour test with the engine developing 36 h.p. at 2800 r.p.m. under continuous load.

It is an in-line engine of monobloc construction, operating on a two-stroke cycle with loop scavenging, with a bore of 92mm, a stroke of 105mm, and a capacity of 1·4 litres. The blower is of the Roots design with two three-lobe rotors and is driven from the front end at about 1·8 times engine speed through vee belts. The maximum output is 37½ b.h.p. at 2800 r.p.m., and a maximum torque of 76 lb/ft is obtained at 1900 r.p.m. Over the flywheel face to the fan the engine is 22·83in long, the overall height and width respectively being 27·95in and 19·69in. The bare weight of the engine is 340 lb, from which can be deduced a specific weight of 9·1 lb per brake horsepower.

The crankcases are of light alloy for automotive purposes and cast iron for marine and industrial applications. In all cases the monobloc construction is such that all diaphragmatic areas are heavily webbed so as to create the utmost rigidity with freedom from distortion and noise.

The swirl combustion chambers are cast into the alloy cylinder head, the heads of individual form being held to the monobloc crankcase at four points.

The pistons are of high-silicon aluminium alloy, similar in design to those found in four-cycle engines, there being no need for firing rings or other similar precautions.

The piston ring arrangement is a wedge-shaped top pressure ring with two Ferrox inserts, followed by three straightforward compression rings above the gudgeon pin, and a stepped and slotted scraper ring below the gudgeon pin. They are not pegged in any way, the face pressure being so arranged that the horns of the rings have almost negative pressure and are under full control when passing over the ports.

A special kind of cylinder liner is used, having the inlet and exhaust ports machined in such a way as to give directional stability to the scavenging. On opposed sides of the liner two sets of inlet ports are arranged partially tangentially and upwards and midway between them are sets of exhaust ports, these being arranged in a radial manner. These two streams of air coming in from opposite sides slightly tangentially and driven upwards and over the column of exhaust gas thus drive it through the radially disposed exhaust ports.

The liners, which are fully machined, are also arranged so that drilled passages form part of the cooling system, and can easily be cleaned by a simple tool in the event of hard water being used for cooling purposes, which may cause furring-up of the drilled passages. The liners are sealed by suitable rings and can be lifted out of the crankcase quite easily for servicing requirements.

The little end bushes are of bronze and pressure lubricated, the big end bearings being of lead-bronze with lead indium plating for the top half bearing, the cap bearing being of Bimetal. As the piston load is always in one direction the gudgeon pin is made a relatively slack fit in the piston. This arrangement prevents sticking of gudgeon pins in the piston bosses, which is often a normal occurrence in some kinds of engine.

The crankshaft is a heavy drop forging, being balanced with its flywheel and front end driving pulley, and has hardened journals. Engine balance is completed by introducing two contra-rotating masses in the two-cylinder or three-cylinder in-line engines.

The flywheel end of the engine has a gear wheel on each side of the block and attached to balance weight shafts, this being loaded to produce a balancing force equal to an opposed force produced by weights keyed to the front end of the shafts and the unbalanced flywheel. The shafts contra-rotate at engine speed and create the necessary balancing couples. The injector pump drive is arranged through these gears at the rear end.

Lubrication is by gear pump driven from the crankshaft through a full-flow filter to the front main journal, then through the hollow crankshaft to the remaining journals and pressure-fed gudgeon pins.

Incorporated in the lubrication system is a ball-loaded by-pass valve arranged in the pump, also a second valve set at a slightly higher pressure on the delivery side of the filter.

Before a sufficiently high temperature is reached viscosity of the oil is such that the full amount cannot be forced through the filter element. With this system oil can be by-passed through a relief valve before it reaches the filter, thus preventing unfiltered oil reaching the bearings when the engine is cold. Metering holes from one of the balance shaft chambers allows a controlled amount of oil to feed the bearings in the Roots blower, suitable outlets being arranged to return surplus oil to the sump. Oil is not fed to the blower rotors, these being operated in the dry condition.

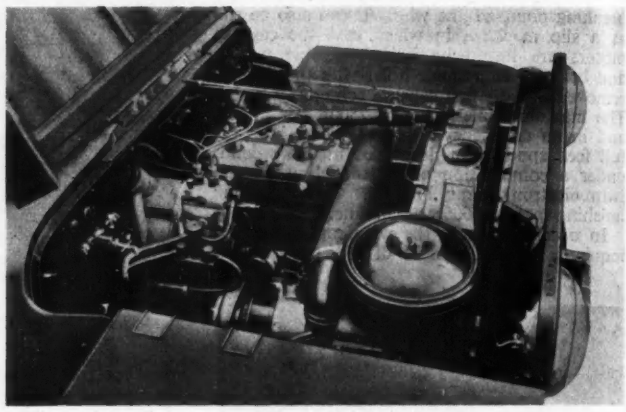

Fig. 2—Two-Cylinder Engine Installed in a "Land Rover"

A fuel injection pump at the front side of an extension of the flywheel housing is driven from one of the balance shaft gears.

A mechanical governor is fitted, this being attached to the front end of the pump, and will be used for all applications initially, but on later models pneumatic governing will be introduced for all automotive purposes, the industrial units retaining the mechanical governor when required.

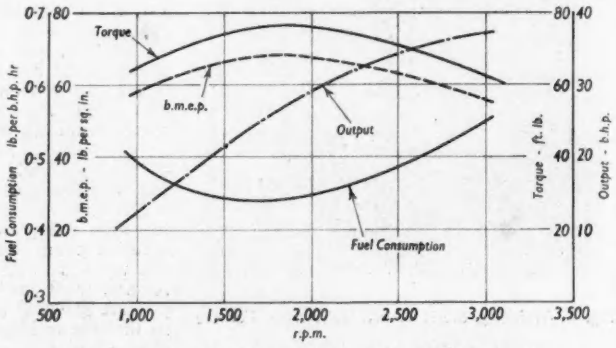

Fig. 3—Performance Characteristics of Two-Cylinder Engine

For automotive engines cooling will be of the usual design and will include a thermostat to control the temperature. For marine purposes heat exchangers will be fitted to all models, an additional water pump being provided for the sea water in the exchanger.

Certain industrial and marine installations will be provided with an additional lubricant cooler

of the oil/water heat exchanger tube stack design.

In explaining its confidence in the superiority of the two-stroke loop scavenge engine the company had prepared a comparison of its characteristics with those of the two-stroke "Uniflow" cycle and the four-stroke diesel cycle. It was maintained that the power/weight ratio of both the two-cycle engines was about the same for, although the superior scavenging process in the "Uniflow" enabled a relatively higher brake mean effective pressure to be developed, the absence of exhaust valve gear with the loop-scavenged engine made it a relatively lighter engine. It had the additional advantage of fewer moving parts and could much more easily be maintained and decarbonised.

The greatest advantage of the range of engines when compared with equivalent four-cycle diesel engines was their smaller size and lighter weight. The three-cylinder and four-cylinder engines weigh 7½ lb and 6½ lb per brake horsepower, as against the 15 lb to 20 lb per brake horsepower of four-stroke engines in the same power category. The four-cylinder Turner engine was stated, in fact, to be lighter than a petrol engine of the same output of 75 b.h.p.

All the engines in this range of loop-scavenged units develop their maximum torque at the same engine speed, have the same maximum engine speed and the same bore and stroke. The three-cylinder engine develops 56 b.h.p. with a maximum torque of 114 lb/ft, the four-cylinder vee engine 75 b.h.p. with a maximum torque of 152 lb/ft, and the six-cylinder vee 120 b.h.p. with 230 lb/ft torque.

These three engines weigh 450 lb, 560 lb and 720 lb respectively. In a series of exhaustive tests made over thousands of miles the two-cylinder engine was fitted in a normal 12 h.p. family car. The car's unladen weight was 24 cwt, which, with an average payload of 6 cwt, made a total of 30 cwt laden weight. The fuel consumption averaged 44 miles per gallon at a cost of 1·05d. per mile, as compared with 2·1d. per mile with a petrol engine of equivalent power.

Spreading a Colliery Waste Heap

THE high rate of dumping on many colliery waste heaps in this country has introduced a number of special problems, and in this connection an interesting piece of work has been carried out by the Distington Engineering Company, Ltd., of Workington, to keep a rapidly growing heap within prescribed limits. The heap concerned is that which takes the waste from Oakdale Colliery and two washeries in Area No. 6 of the South-Western Division of the National Coal Board. This heap is fed by an aerial ropeway, which is in operation for about fifteen hours each day. The rubbish is tipped between the ropeway standards, 150ft high, and it was required that the height of the heap should not exceed 100ft. The rate of dumping amounted to approximately 1250 tons per day, and when it became obvious that this rate would bring the height of the heap up to the 100ft level within a matter of months rather than years, two small bulldozers were introduced to spread the heap.

For a time the bulldozers dealt satisfactorily with the spreading, but the greater the distance through which the material had to be moved, the less became the volume that could be moved within a given time. For this reason, at the beginning of April, 1953, it was decided to experiment with a Distington-Goodman shaker conveyor drive, together with a duckbill loader and 100 yards of steel troughing and ancillary equipment in order to increase the area over which the rubbish could be spread. All this equipment was of the standard kind frequently used underground in this country for driving headings and drifts. For its use an area of about 15 yards square was levelled near the top of the heap to the south side, and the duckbill loader, a swivel trough, half of a telescopic trough, the drive and drive trough, and a trough at the discharge end of the drive, were installed. The duckbill loader used can be automatically extended and retracted over a little more than 12ft and can be manually swivelled through an arc of 60 deg. with a centre at the pivot of the swivel trough. This loader can be seen in operation in the illustration below. Its width of clean-up when fully retracted is about 23ft and when fully extended 35ft. The shaker conveyor and loader were located so that rubbish was discharged from aerial ropeway buckets within the clean-up area of the duckbill which loaded the rubbish and fed it along the shaker conveyor.

Duckbill Loader in Operation

The normal process of loading with the duckbill produces a dirt bunker, into which freshly tipped rubbish falls, but the duckbill is able to continue loading older rubbish when the aerial ropeway is stopped. At all times tipping and spreading can proceed independently.

The shaker conveyor discharges the rubbish down the side of the heap and in due course a pile of rubbish builds up almost to the level of the discharge point. At this stage the smaller of the two bulldozers originally employed is used to spread the material over a distance of 10 yards in various directions beyond the conveyor discharge point. Originally it was intended to dispense entirely with both bulldozers, but landsliding made it impossible to provide a sufficiently consolidated and stable platform of debris on which to extend the shaker conveyor.

Extension of the shaker conveyor is effected by the addition of steel troughs, each 13ft in length, bolted together and mounted at their junctions on ball-bearing guide frames, supported on improvised steel chocks. An extension is made usually after about 20,000 tons of rubbish have been handled.

After wet weather there is sometimes a landslide, which may reduce the level of the platform of debris over a distance as much as 10 yards from the edge of the heap. The conveyor troughs then fall out of line to a degree greater than is permissible, and need additional support until the bulldozer brings the sunken shelf up to datum level by spreading more rubbish.

Since the beginning of April there have been a number of difficulties peculiar to this unusual application of underground mining machinery to surface work. Not only have the loader and conveyor to deal with all the rainfall which the rubbish will absorb, but also they have to handle washery shale under 3in mesh with a water content of 6 per cent. The mass of fine shale therefore has fluid characteristics.

The duckbill extensible shovel trough is supported at one end by the tip of the shovel and at the other by an adjustable sliding shoe. To prevent the duckbill loader from sinking into the soft ground a simple raft 12ft square was fabricated from corrugated roofing bars and laid beneath the duckbill and the swivel trough.

Anchorage of the shaker drive on soft ground presented a problem which was successfully solved by bolting the drive to a framework of old R.S. joists; the lower members of the framework with 12in webs being arranged transversely to the line of troughs and buried in the ground. This framework prevents any movement of the drive due to reaction, and can be easily dismantled and moved with the shaker conveyor equipment. More material can usually be loaded on the level by the duckbill than can be conveyed without spillage by standard troughing. Rather than restrict the rate of loading to any great extent, the capacity of the troughs was increased by welding strips of steel plate ¼in thick and 3in deep to the flanges.

We are informed that in the few months that the machinery has been installed it has spread over 180,000 tons of rubbish, or the equivalent of about 7250 tons a week of wet material. The labour employed on the installation consists of one operator per shift and one man a day on maintenance.

Book of Reference

Electricity Undertakings of the World, 1953–54: *The Electrical Journal Red Book*. London: Benn Brothers, Ltd., 154, Fleet Street, E.C.4. Price 30s—This edition, the sixty-third in the series, was the last to be edited by Mr. Stanley G. Rattee, whose death occurred at the time when the book was going to press. Additional information concerning British Commonwealth and foreign undertakings is included in the book. Among the foreign countries about which new details are given are Colombia, Crete, the Dodecanese Islands, Greece, India, Japan, Madagascar and the U.S.A. Users of the book will be interested to know that the addresses of overseas undertakings are now included. Despite the difficulty of obtaining information from certain countries such as Korea, China and parts of Eastern Europe, much new data about some of these places have been included. The sections of the book dealing with the British Electricity Authority, the Area Boards, the North of Scotland Hydro-Electric Board and other electricity authorities follow the form of recent editions, but the material has been revised throughout.

Metallurgical Topics

Cathodic Protection

ONE HUNDRED AND THIRTY years ago, the British Navy, acting on the advice of Sir Humphry Davy, adopted the practice of protecting the copper sheathing of wooden ships from sea-water corrosion by the attachment of blocks of a baser metal, usually zinc. Apart from the continuance of this practice for the protection of bronze propellers and other copper alloy components, many applications of this form of galvanic protection were made intermittently during the following 100 years. In the last two or three decades, however, cathodic protection, originating in principle from Davy's work, has developed in its various aspects into such an indispensable adjunct to the design of all buried or submerged structures as to call into existence a new class of corrosion engineers, with, in America, a very active National Association of Corrosion Engineers.

A Symposium on "Cathodic Protection" was held on Friday, November 13, 1953, under the auspices of the Corrosion Group of the Society of Chemical Industry, with Dr. J. C. Hudson in the chair. Seven papers were presented, including one each from the United States, Canada, Belgium and the Netherlands. The first paper at the morning session was by K. A. Spencer (consulting engineer, London) on "Cathodic Protection in Relation to Engineering Design." Mr. Spencer dealt with protective coatings in general and the factors affecting applications of cathodic protection. Differences in design, in the quality of protective coatings when present, and in environmental conditions, made it necessary to give individual study to each structure before it was possible to specify a satisfactory cathodic system to protect it. The choice between the use of the sacrificial-anode and the power-impressed type of cathodic protection was entirely dependent on the design of structure, the locality in which it was situated, the electrolyte conditions, availability of power supplies and economics. Magnesium anodes were extremely useful for isolated marine structures where electrolyte resistivity was low and no power was available, but the use of sacrificial anodes, such as magnesium, aluminium or zinc, was limited in the case of buried structures by the effect of ground resistance. In practice it was necessary to make a ferrous structure more negative than 0·85V (relative to the copper/copper sulphate half cell) to the containing electrolyte in order to obtain protection, but the intensive corrosion due to sulphate-reducing bacteria could only be countered by using a metal/electrolyte potential of −0·95V. The design of a system of cathodic protection was described in detail for several kinds of structures, e.g. pipelines, tanks, jetties, steel bridges, buoys and pontoons, ships, oil/water separators, tubular condensers, pumps, power transmission pylons and underground cables. The design of cathodic protection schemes was a relatively new aid to the civil and structural engineer in preserving the outcome of his efforts. The cost of corrosion engineering design and survey plus the equipment for the application of cathodic protection was usually small relative to the value of the structure, including the civil engineering work involved, and was seldom as much as the cost of coating materials and their application, which do not provide alone the answer to corrosion deterioration for buried and submerged structures.

The next paper, by M. Oudeman (Koninkliyke/Shell-Laboratorium, Amsterdam) was on the "Influence of the Composition of Magnesium Anodes on their Efficiency." It was stated that some of the magnesium anodes used in the protection of a buried pipeline were found to be abnormally inefficient, being excessively corroded and yielding small currents. This was attributed to a high content of aluminium (12 per cent) and of general impurities, especially iron. These anodes had also undergone some intercrystalline corrosion, possibly due, as suggested in the ensuing discussion, to casting defects in the form of inclusions of flux. A laboratory method for the assessment of anode efficiency was described.

A paper on the "Development of Cathodic Protection in Belgium," by A. Weiler (Société de Distribution du Gaz, Brussels), outlined the history of cathodic protection in Belgium where the first experiments on these lines were made in 1933 in the course of a campaign against stray currents which were affecting a network of pipelines. By the co-operation of all concerned, railways, electricity, gas and water undertakings, a solution was found which has led to a general adoption of cathodic protection, the efficiency and economy of which has been abundantly demonstrated. In areas not affected by stray currents, sacrificial zinc anodes had been used since 1937 and sacrificial magnesium anodes since 1946; elsewhere they would not generate a sufficient potential difference. It was most desirable to apply cathodic protection immediately a pipeline was laid, because this preserved the efficiency of the coating. On the other hand, it was by no means easy to apply it to an old pipeline that had already suffered corrosion, for it might prove very costly to secure electrical continuity in the pipe and to insulate it from other structures.

The last paper at the morning session was on the "Economic Aspects of Corrosion Control," by D. H. Lewis and O. C. Mudd (Shell Pipeline Corporation, Houston, Texas, U.S.A.). The material, opinions and conclusions contained in this paper were drawn from the authors' experience in the operation of some 6100 miles of buried pipelines, and in stressing the economic aspects of corrosion control, they revealed the role of cathodic methods in a properly balanced programme. From 1917, when the first sections of Shell's crude pipeline system were constructed, to 1935, when the first efforts to lower the leak-frequency rate were made in the most severely affected areas, the corrosion of the buried pipelines became an increasingly important economic factor. From that date the accumulated leak curve showed a tendency to flatten out. Protective coatings and cathodic protection each had advantages and limitations, and under severely corrosive conditions the two systems, each supplementing the other, produced optimum results. Galvanic anodes provided a practical solution at isolated locations where local generation would be too costly; but in highly corrosive areas and over long periods of time, the dry type rectifier connected to public service power was more favourable from the viewpoint of investment, maintenance and operating charges. Galvanic anodes attained their highest economic value when used as a remedial measure to mitigate localised corrosion on either bare or partially coated pipe. With zinc anodes electrical recovery was very high, but with magnesium the useful current seldom exceeded 60 per cent of the theoretical amount. On the other hand, zinc and iron developed a difference of only about 0·3V in most soils, while magnesium gave about 1·1V under similar conditions. The use of zinc was generally restricted to soils of low resistance. Corrosion control was most economical when undertaken as a preventive rather than a remedial measure.

In the afternoon the first paper was on "Cathodic Protection and Control of Corrosion in the Middle East," by W. C. R. Whalley (Iraq Petroleum Company, Ltd., Tripoli, Lebanon). After outlining the influence of soil corrosivity in relation to climate and topography, Mr. Whalley gave details of the types of installation employed for generating power, rectifiers for any site at which alternating current was available and diesel-engined generators at places remote from an existing source of power. Galvanic anodes found considerable, though diminishing, application in the Middle East, mainly in sea-water or in marshy areas. Magnesium was invariably used, though the electro-chemical efficiency of magnesium installations was seldom found to exceed 40 per cent in Middle East conditions. Details were given of cathodic protection of pump stations and tank farms, including special protection of tank bottoms against the highly corrosive ground on which they were situated. Jetties in the Persian Gulf were now being protected by rectifiers with scrap iron as the anode. It seemed immaterial where the anode was located in relation to the jetty provided that it was in the sea-water. Buoys were protected by small magnesium anodes attached to each buoy. Submarine loading lines, stretching 4000ft to 8000ft from the shore into deep water and used for loading ocean-going tankers, were protected by magnesium anodes attached at intervals along the length of the sea line. At one time it was considered that the use of current generated externally might involve some hazard of sparking at the time of disconnecting the loading hoses on the tanker. It now appeared, however, that such a possibility was remote, and a number of rectifier installations were in use.

The last two papers were concerned with naval applications. In the first of these, on "Cathodic Protection as Applied to Royal Canadian Naval Vessels in Active Service," by K. N. Barnard (Naval Research Establishment, Dartmouth, Nova Scotia), techniques were described for fitting cathode protection systems to different classes of ships in the Royal Canadian Navy. Since 1946, experience had shown that cathodic protection in conjunction with paint was an economical system for preventing corrosion and fouling of ships in sea-water, and that there were several methods to choose from. A magnesium anode system had been applied to more than fifty active ships ranging from an aircraft carrier to light harbour craft. The efficiency of the system was dependent on the design, location and method of securing the anodes (all of which had now become standardised) and also on the composition of the anodes, the 91 : 6 : 3 Mg-Al-Zn alloy being much inferior to the 96 : 3 : 1 alloy. For economic reasons, steel anodes, energised by an applied direct current, have been fitted to the larger ships, but it has become standard practice to attach a few magnesium anodes near the stern to take care of the greater current required in this area owing to the presence of the bronze propellers. Graphite anodes, energised by direct current, were said to be satisfactory, but their development was still in an experimental stage, and a platinum anode installation was under consideration. Precautions to be observed in fitting the different systems were discussed and working rules given for the amount of material that must be fitted to secure protection for a minimum period of two years between dry-docking of the ships.

In the last paper, on "Cathodic Protection: Its Application to Ships and Establishments of the Royal Navy," by J. T. Crennell (R.N. Scientific Service, Portsmouth Dockyard), the Admiralty's present work on cathodic protection was briefly described. Cathodic protection of the outer bottoms of H.M. ships was at present applied only to the Reserve Fleet. Single ships were protected by magnesium anodes, groups of ships by impressed current. In fresh water, protection by magnesium anodes was impracticable, and impressed currents had to be so high to maintain protection of distant parts that local damage to paint became probable. Cathodic protection was not applied to ships laid up in fresh water, in which, fortunately, corrosion was much more uniform and therefore of less consequence. Jetties were protected by impressed current, scrap steel anodes being laid on the sea bed. Floating docks in the Far East were protected by magnesium anodes. In enclosed spaces on board ship, which might be filled with sea-water, cathodic protection involved a risk of hydrogen collecting in pockets. The only safe way of providing protection appeared to be by the use of zinc anodes. Commercial zinc protectors, fitted on ships' outer bottoms, remained active for only a very short time; but laboratory experiments showed superior performance by high-purity zinc (99·99 per cent)

and by the 99·7 per cent quality with the addition of 1 per cent of magnesium. Amalgamation of either material gave a major improvement in active life. Consideration had been given to methods of protection of aluminium alloys which were being used to an increasing extent for hulls of small ships. It was found that the potential giving cathodic protection to aluminium was the same as that required for steel. This meant that aluminium or, with certain exceptions, aluminium alloys, could be used as underwater fittings on the hull of a steel ship without risk of corrosion, if the steel ship was cathodically protected.

A short discussion followed the reading of each paper and the meeting terminated with a more general discussion. The assumption made in the papers that the basic principles of the subject were well understood was perhaps not fully justified, and valuable contributions on this aspect of the subject were made by speakers from Cambridge University and from the Chemical Research Laboratory, Teddington. A lively interchange of views took place on the relative merits of high-purity zinc and magnesium as sacrificial anodes, and there were evidently divergent opinions as to the value of partial protection. The organisers are to be congratulated on a very successful meeting. A full account of the proceedings is expected to be published in due course by the Society of Chemical Industry, possibly in the form of a special report or brochure.

Test for Quench-Cracking

ALTHOUGH it is realised that the best mechanical properties, including fatigue limit and impact value, are obtained in a steel by tempering a structure of 100 per cent martensite, the risk of inducing dangerous quenching stresses often limits an approach to this ideal condition. Quenching stresses arise from thermal gradients and the volume changes in transformation of austenite to martensite ; and certain conditions which can minimise the risk of cracking may be deduced from theoretical considerations. For example, J. H. Hollomon and L. D. Jaffe, who devote Chapter 7 of their book to the subject, hold that the problem of finding the composition

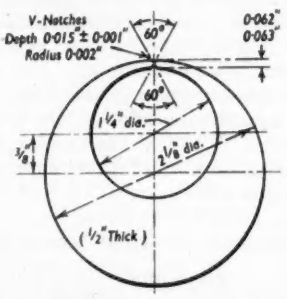

Fig. 1—"Crackability" Test Piece Adopted by Chapman and Jominy

that has a minimum tendency towards quench-cracking resolves itself into one of obtaining the composition that provides the desired hardenability with the maximum martensite temperature range and with the minimum carbon content necessary to obtain the desired strength with the heat-treatment procedure employed.* To check such conclusions and extend the data on quench-cracking, R. D. Chapman and W. E. Jominy† have devised a "crackability" test specimen of the form shown in Fig. 1. This specimen in different steels was quenched under a variety of conditions. As soon as it had cooled to the temperature of the bath, or to room temperature after being cooled in a salt bath, it was roughly polished, examined for cracks under the microscope or by magnetic methods, and tested for hardness on the heavy section and also on the thin section. It was then cold-treated at about −75 deg. Cent. for sixty minutes, again polished, examined and the hardness measurements repeated. From tests on over twenty carbon and low-alloy steels, Chapman and Jominy concluded that the higher the temperature from which the steel is quenched, the more likely it will be to crack ; that cracking tendency was related to the temperature (*Ms*) at which martensite began to form on cooling, and the lower the *Ms* temperature the greater the tendency to crack. The tendency to crack was increased by increase in carbon content, and by greater hardenability. Quenching in molten salt is less severe than in oil, even when 100 per cent martensite is formed, but when steel is hardened to 100 per cent martensite there is more tendency to crack than when appreciably less martensite is produced by the quench.

Most of these conclusions have already been accepted from practical experience, but the use of a specimen which must give a certain minimum hardness without cracking may be of considerable assistance in the choice of a steel for a specific purpose.

Vacuum-Melted Metals

THE advantages of vacuum melting are discussed in an article on "Some Aspects of Vacuum-Melted Metal," by J. H. Moore,[1] who defines the four basic effects of the procedure as (*a*) simple protection against reaction with atmospheric gases, (*b*) dissociation of certain gas-metal compounds, (*c*) minimising the amount of dissolved gas, and (*d*) acceleration of bath reactions which have gaseous products. The usual vacuum-refining treatment of a metal or alloy may involve more than one of these. For example, in the production of vacuum-melted beryllium-copper alloy, the loss of beryllium is reduced from 10 per cent to practically nothing and the product has a diminished gas content. In the nickel-base, age-hardenable, high-temperature alloys a major benefit is the avoidance of excessive loss of reactive hardening elements through oxidation. This is particularly true when scrap is being remelted. Dissociation of gas-metal compounds (e.g. oxides, nitrides, hydrides, &c.) occurs when the pressure of the vacuum attainable in practice is less than the dissociation pressure, a condition which applies to most nitrides and hydrides, and also to the oxides of copper and nickel, but not to those of iron or aluminium. Similarly, metallic impurities having a high vapour pressure are diminished in amount by vaporisation. This effect has an important bearing on the removal of lead, zinc, bismuth, antimony, &c., in the vacuum-melting of copper and nickel alloys. The effect of a vacuum on a refining reaction may be illustrated by the reduction of carbon in high-purity iron by the formation of carbon monoxide. The progress of this reaction under one set of conditions, together with the elimination of nitrogen and hydrogen, is shown in Fig. 1. The importance of the container is illustrated by the complicating re-oxidation of the iron by the magnesia crucible.

At present, the principal metals being vacuum-melted are copper and nickel and their alloys, such as electronic tube materials, magnetic alloys, sealing alloys and alloys with controlled coefficients of thermal expansion. To these must be added platinum and its alloys for thermo-couples, which were among the first materials to be so treated. Vacuum-melting of many non-ferrous alloys, originating from Dr. W. Rohn's "Heræus Vacuum Schmeltze," 1923, has been an established practice for many years.

VACUUM-MELTING OF STEELS

Recently, the vacuum-melting of steels (which, however, has been studied experimentally for over twenty years) has received greater attention, with special reference to the fatigue endurance and creep properties of the product. Results of some of these investigations are summarised in this article by J. H. Moore. Very low gas content in solution at solidification has been shown to have important effects on the properties of chromium-iron alloys. The ductility of the high-chromium alloys has been shown to depend on the carbon, nitrogen and oxygen content, though there is some disagreement as to the relative importance of oxygen. The effect on the notched-bar impact value was very marked, the impact figure of the vacuum-melted product being about 100ft-lb, as compared with 0ft-lb to 8ft-lb for the commercial product. Vacuum-melted 18 : 8 stainless steel with very low carbon and nitrogen (total 0·006 per cent) showed decidedly better creep resistance than commercial extra-low-carbon 18 : 8 stainless steel of the same kind. An analogous effect was observed in pure iron. A reduction in the nitrogen content of a high-purity iron, from 0·009 per cent to 0·0001 per cent, by vacuum-melting was accompanied by an increase of 57 per cent in the fifty-hour creep rupture stress at 427 deg. Cent. and of 76 per cent at 482 deg. Cent.

It is not only in these low-carbon products that these advantages of vacuum-melting are observed. The high degree of cleanliness obtainable in vacuum-melting by avoiding slag inclusions and deoxidisers has a beneficial effect on behaviour in fatigue. A considerable improvement in the rotating-beam fatigue life of high-carbon-chromium steel is attributed to an increase in cleanliness, which eliminated many sub-surface as well as surface stress raisers. J. H. Moore himself compared the fatigue behaviour of a commercial ball bearing steel with that of a

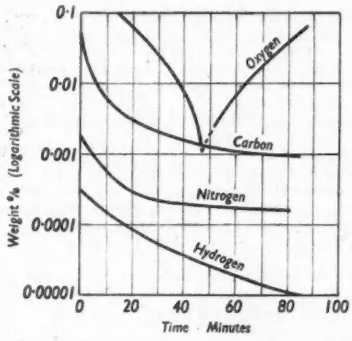

Fig. 1—Curves for Degassing During Vacuum Melting of Iron in a Magnesia Crucible (J. H. Moore)

steel of the same analysis prepared in a vacuum furnace, and found an 85 per cent increase in the fatigue stress giving an endurance of 10^8 cycles.[2] In a recent paper, J. T. Ransom[3] compared the fatigue properties of a commercial steel containing carbon 0·4, nickel 1·8, chromium 0·9, and molybdenum 0·3 per cent with those of a vacuum-melted synthetic product of approximately the same composition, heat-treated to nearly the same Rockwell hardness. The longitudinal fatigue limit of the vacuum-melted steel was slightly higher than that of the commercial steels, but this may have been due to its slightly greater hardness. The important effect, however, was shown by the fatigue limit of specimens taken transversely to the direction of forging. Whereas the longitudinal fatigue strength was raised by about 14 per cent, the transverse fatigue limit increased from about 80,000 lb per square inch for the commercial steels to 120,000 lb per square inch for the vacuum-melted steel, an increase of the order of 50 per cent. The ratio of transverse to longitudinal fatigue limit increased from 0·6 for the commercial steels to 0·86 for the vacuum-melted steel.

The transverse fatigue limit of forgings made by conventional steel-making practice is less than the longitudinal fatigue limit largely because of the presence of elongated inclusions. The author (J. T. Ransom) rightly claims that the increase of the transverse fatigue limit obtained in his experiments by elimination of all inclusions of measurable size is large enough to provide justification for steel-making research aimed at obtaining similar improvements in the transverse properties of commercial steels. He recognises that complete elimination of inclusions on a commercial scale, by vacuum-melting or by other means, is impracticable at the present time and may not be possible at all. Nevertheless, the possibility remains of practical commercial development towards the improvement of the transverse properties of high-quality steel forgings by ensuring that inclusions are smaller in amount and less deleterious in size and shape—and, it may be added, that phosphorus content (which was "nil" in Ransom's vacuum-melted steel) is reduced to a minimum.

* *Ferrous Metallurgical Design*. London : Chapman and Hall. Page 226.
† *Metal Progress*, September, 1953, page 67.

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[2] *Iron Age*, April 2, 1953.
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ENGINEERING WAGES

On Thursday of last week, the executives of the unions comprising the Confederation of Shipbuilding and Engineering Unions decided to recommend a twenty-four-hour stoppage of work as a protest against the rejection of the recent claim for a 15 per cent increase in wages. It is an astonishing decision, for the threatened stoppage, if carried out next Wednesday—which is the day appointed—can in no way strengthen the claim. Its principal effect will be the loss of a day's production in the engineering and shipbuilding industries as a whole, and of more than a day in some of them. It will cause at least a day's delay in the fulfilment of important export orders, and it will involve, too, the loss of a day's pay for all who decide to take part in what is being called a "token strike." Nobody seems to benefit. Everyone concerned, including the nation at large, suffers a loss. At the time of writing, it is by no means clear just what response will be made to this majority decision of the union executives, as it appears that the rules of several of the individual unions concerned require a ballot before any official strike action can be taken. Nevertheless, the threat has been made.

The present wage dispute is the fourth which has arisen in the engineering and shipbuilding industries in the last four years. In 1949 a claim, which was originated by the Amalgamated Engineering Union, for an increase of £1 a week in the wages of adult male workers, was put forward by the Confederation of Shipbuilding and Engineering Unions, and after lengthy negotiations, in which the Ministry of Labour took part, increases ranging between 8s. and 11s. a week were agreed upon in November, 1950. Less than a year later, in October, 1951, another claim was advanced for an all-round increase of £1 a week, the result of the ensuing negotiations being a rise of 11s. a week and the granting of a second week's paid holiday. A few months afterwards, in April, 1952, the Confederation formulated another claim for a "substantial increase," which was subsequently amended, following a recommendation from the A.E.U. national committee, to a demand for an increase of £2 a week. That claim was rejected, and there followed talk about strike ballots and the banning of overtime. Later last year, however, negotiations were reopened, and they led in November to wage increases of 7s. 6d. a week in the shipbuilding and ship repairing industries and of 7s. 4d. a week in the engineering industry. But when the A.E.U. national committee held its annual conference in May this year, a resolution was carried in favour of a new claim for a 15 per cent increase on the consolidated time rates of all grades of male workers. The Confederation of Shipbuilding and Engineering Unions endorsed the claim and submitted it to the employers early in July. This claim, it was stated, was based on the rising cost of living, the increased productivity in the industry, and increased profits, and after full consideration and joint discussion it was finally rejected by the employers' federations earlier this month. During the negotiations on the claim the Engineering and Allied Employers' National Federation emphasised two or three specially important points. It was pointed out that, whilst between January, 1948, and July, 1953, the retail price index had increased by 35·6 per cent, the average weekly earnings (as distinct from wage rates) of adult male workers in the engineering industry had risen by 48 per cent for timeworkers and 47 per cent payment by results workers. Furthermore, in the year ended May last there had been a reduction of 25 per cent in the volume of orders reaching the industry, which had followed a decline of 8 per cent in the preceding year. It was also made clear that, in the majority of cases, the industry did not increase prices to cover the wage increases granted last year. Since then there have been instances where prices have had to be reduced in order to secure business and to meet growing competition. Any advance in wage rates now would obviously compel an increase in prices. Such a move could only seriously imperil the engineering industry's ability to maintain even its present export rate, at a time when it is imperative that export business should be not merely maintained, but increased.

All these facts are, of course, well known to the trade union leaders who have been taking part in the recent negotiations. But they appear, nevertheless, to have reached the conclusion (upon what strange arguments it is difficult to conjecture !) that a workless day will somehow assist their cause, and have informed the Minister of Labour of their decision. Since that decision was taken last week, the Chancellor of the Exchequer, in a statement to the National Production Advisory Council—on which the unions are represented—has again remarked on the key part which the engineering industry has in increasing the total volume of the country's exports, and has also stressed that, in the first three-quarters of this year, the volume of engineering exports was lower than in the corresponding period of last year. The engineering industry is in no sense averse to bigger earnings ; but bigger earnings now are very much dependent upon a bigger volume of exports, and it daily becomes plainer that the curve of engineering exports cannot rise unless the products of the industry can be offered at strictly competitive prices. The unions, like the employers' federations, are well aware of that situation. But the current tactics of some of the constituent members of the Confederation of Shipbuilding and Engineering Unions can scarcely be interpreted as assisting in any way to meet what is a pressing need of the moment. In the context of arguments for and against an increase of wages the decision to have a one-day strike appears as a baffling irrelevance. It cannot do any good ; it is certain to do some harm ; and if it raises the temperature of discussion it may do even more harm. It is still not too late for the union leaders to engage in wiser second thoughts on the matter.

LOCOMOTIVE TESTING AT SWINDON

In the last few years we have several times commented upon the gradually improving technique in this country for the testing of locomotives, and we have reproduced details of trials carried out under the auspices of the Locomotive Testing Committee of the British Railways. Not many years ago it could be said with some truth that the steam locomotive, although one of the oldest forms of motive power, was one of the least understood ; but now one has only to study the remarkable paper presented to the Institution of Locomotive Engineers by Mr. S. O. Ell, on November 18th, describing recent work at Swindon, to realise that at long last it is possible to establish the performance characteristics of a steam locomotive with the accuracy and precision hitherto thought possible only with electrics and diesel electrics. The exactness with which readings taken on variable speed road tests fall on to a fair curve corresponding precisely to the results of analytical tests taken on the stationary testing plant is sufficient guarantee of the soundness of the methods employed. Combined with this

notable development has been the experimental verification of design data, particularly in regard to improved draughting arrangements at the front end, which have resulted in some spectacular augmentation of maximum steaming capacity of various types of locomotive, ranging from the increase of 89 per cent achieved on a 2–6–0 of L.M.S. origin to an increase of 30 per cent on a locomotive of such established success and reliability as the Great Western "King." But as several speakers emphasised in the discussion upon Mr. Ell's paper, this boosting up of maximum steaming capacity should be regarded more as an insurance policy against the effects of inferior fuel rather than a hint of vastly heavier trainloads to be worked in the future.

Coal, indeed, is the predominant factor that governs much of engine performance to-day. While it is now possible to predict with complete accuracy the speed at which a particular load may be worked in any set of regular steaming conditions, any such predictions may be completely falsified if the engine crew get into trouble with bad steaming. The effect of the improved draughting arrangements is to make possible once again the running of the nineteen-thirties with the coal of to-day. But the improvement in draughting, important though it is, represents only one side of the testing practice and results achieved at Swindon. The fundamental problem has been to establish precise relations between the thermodynamic performance of the locomotive and the resulting motion of the train: in other words, to relate basic coal consumption to the operation of the booked train service. From the actual test results a technique has been developed for the production of speed-distance curves for any combination of loading and gradients; hence time-table schedules can be prepared which not only correspond to the natural performance characteristics of the locomotive, but which by relating the speed to the load of the train, will ensure that the service will be worked at the particular rate of evaporation that corresponds to the minimum basic coal consumption. In this way the practice of locomotive testing is rendered of direct practical value to the operating and motive power departments of the railway.

The value of the precise test data now obtainable does not, however, end nowadays with the planning of time-tables and the economic use of motive power. The optimum performance of locomotives is of direct practical concern to the civil engineer and to the signal engineer, for the test engineer can, from an examination of gradients in conjunction with train loads, answer with certainty the question: "What is the highest speed at which a train is likely to pass a certain point?" From the answer the civil engineer can determine the standard at which his track must be maintained, and the degree of super-elevation necessary on curves, while the signal engineer is provided with data to assist him in the siting of distant signals in order to give adequate braking distance. Around the scientifically determined performance characteristics of the various types of locomotive the whole edifice of railway engineering and operating may now be built. As the results set out in Mr. Ell's paper so clearly reveal, the basis is now wholly sound. And yet one cannot fail to be struck by the extreme simplicity with which the fundamental quantities are obtained. For example, the ingenious steam flow meter fixed to the blast pipe is not used for direct measurement but merely as a guide to the driver in his adjustment of the cut-off; instead the very simple "summation of increments" method is used to establish beyond any doubt the precise straight-line relation between the coal consumption and the boiler feed, and to check the continuance of that straight line throughout the duration of the test. It is, no doubt, in this happy combination of clearly defined objectives, sound underlying principles, and simplicity in procedure that such convincing results have been attained.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

MOTORSHIPS FOR CLYDE SERVICE

SIR,—Looking back over some previous issues of your journal, I chanced to find an article on the above in your issue of June 5, 1953, from the pen of G. W. Tripp, O.B.E., F.C.G.I., M.I.C.E., pages 792 and 793. This subject happens to be very near to my heart as a Glasgow man; but, let me hasten to state that I am not an engineer, but write purely from the non-technical angle. The Clyde Steamer Services of the old days—up till 1939, were the pride of every Glaswegian and every Clydesider. And in these days, when fleets of trim Clyde steamers plied daily from the original Broomielaw—on the north side of the river, adjoining the Caledonian Railway Bridge—there were not enough steamers to accommodate all the passengers who wished to sail "Doon th' watter," while at holiday times thousands were left behind.

In these days there were piers at Govan and Renfrew, but with the march of progress (?) these piers were closed and as a further progressive move most of the steamers themselves were discontinued, only sailing from Gourock and Craigendorran Railway Terminal Piers. I believe that now, to-day, only one or, at most two, steamers ply from the new Broomielaw on the south side of the River Clyde. I disagree most emphatically with your author when he states in his closing paragraph that the Railway Executive are trying to revive the former popular service—with the introduction of their new fleet of "Toy" steamers.

Early as it is yet, the "makeshift" which was put on recently after being transported by road from Loch Tay proved a most hopeless proposition on the tempestuous waters of the Forth in stormy weather, and many persons who have been forced to travel from Rothesay to the Tail of the Bank to travel by rail to Glasgow have sworn—never again. These toy steamers may be all right on calm water on a beautiful June day, but, after all, ours is a twelve-month service and we expect that at least what the good old steamers could do surely in 1953 new fleets can do, too. If the Railway Executive really wish to see a real return to the old and highly popular sailings, all they need do is put on—not off—a similar fleet of really good, efficient and trustworthy and graceful-looking ships of the type so dear to the hearts of all Clydesiders.

To the technical man, the new "Maid" class may have points which appeal to themselves, but I am afraid these points only appeal to themselves, and the ordinary man who is only interested in that "sail doon th' watter" is at a complete loss to understand why his day's sail should be marred by sea-sickness in a "cockle" or small toy boat, which cannot ride the swells which the old ships took, unnoticed, in their stride.

Also, he cannot understand why, particularly at busy holiday times, he has to queue at one of the big railway stations for a train to take him to Gourock, Wymesbay or Craigendorran before he can hope to get the sail he has waited all year for. To the average Glaswegian 90 per cent of the interest in his sail "doon th' watter" is centred on the shipbuilding yards which line both sides of the river almost all the way from the Broomielaw to Dumbarton, and from thence he looked with interest and anticipation for the yards at Port Glasgow and Greenock. Replace his source of interest and all the bus tours in the country will not stop him—and his family—from a day down the Clyde. That is the secret, and the only secret, of the popularity that once was, if the Railway Executive only had the brains to realise it.

JACK R. WOOD

Rutherglen, Lanarkshire,

[Our correspondent has, perhaps, failed to realise three important points: (1) The financial aspect. For years Clyde steamers have been run at a loss, and the Railway Executive hopes with these smaller and more economical craft to turn the loss into a profit. Certainly a vessel of 400 tons gross is hardly a "toy." (2) The serious competition of the motor-coach, which can economically offer lower fares than can rail or steamer, and (3) that the number of enthusiasts whose main interest is to see the shipbuilding yards of the Clyde is relatively small compared with those whose desire is to see the natural beauties of the lower Firth.—ED., THE E.]

HARROW ACCIDENT

SIR,—I have looked in vain for official comment on the letters from Messrs. Lawrence and Whitmore published in your issues of September 4th and 18th respectively.

Surely the strong probability of a mishap to one of the water gauge cocks should be investigated in the light of the signalman's statement that he could see neither driver nor fireman as the engine passed his box, and in view of the fact that the gauge glass cock had been broken off although the glass itself was intact.

Can nothing be done to rouse railway officials from their slumbers in their little ivory towers? They appear to be completely indifferent to the interest which the public takes in the railways and to the concern that so much appears to be wrong.

E. B. PARKER

Wirral, Cheshire,
November 6th.

[It is the general policy of railway officials not to intervene in correspondence in the Press. On their behalf may we assure Mr. Parker that there is plenty of evidence that note is taken by them of his and other people's opinions. Those who are silent do not always slumber.—ED., THE E.]

FILING DRAWINGS

SIR,—The problem of suitably filing production prints and drawings in the drawing office and print room at a large factory where I am employed is progressively getting worse. The traditional plan cabinets take up a considerable amount of space, and although quite expensive to purchase they do not house the drawings in a convenient manner, either for filing or extracting the drawings from the drawer-file. I would be most grateful to receive any suggestions of alternative methods of housing drawings in fairly large numbers.

M. JONES

Penarlag, Hawarden,
November 20th.

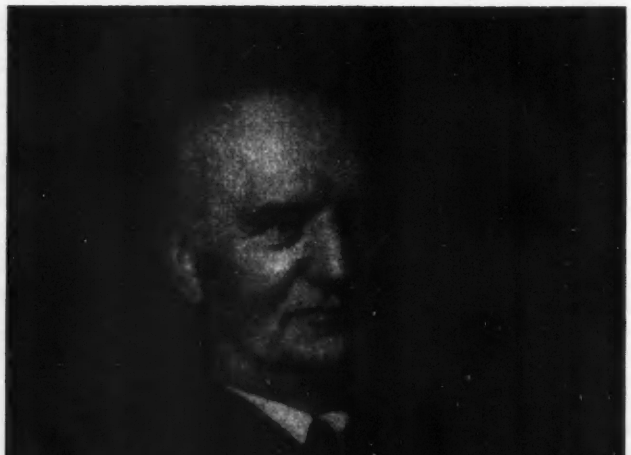
Obituary

LOUGHNAN ST. LAWRENCE PENDRED, C.B.E.

LAST Friday, a few days before his eighty-third birthday, there died Mr. Loughnan St. Lawrence Pendred, C.B.E., Editor-in-Chief of this journal from 1905 to 1946. Often in these columns we are called upon to record the deaths of famous men, of men who gained the admiration, the respect and the esteem of their fellows. But never, not even upon the death many years ago of Loughnan's father, who had preceded him in the editorial chair, have we done so with such regret and so great a sense of personal and irreparable loss. For, over a period of forty years in the editorial chair, Loughnan Pendred personified THE ENGINEER and after his retirement in 1946 those who had worked under him and even those later arrivals who knew him only by his occasional visits to this office were very much aware how his influence permeated their work. For his was indeed a powerful personality, but one which, besides winning him respect and esteem, earned for him also the deep affection of all who came to know him closely.

Mr. Loughnan Pendred was born in 1870, the second son of his father. He was educated at the Central Institution, South Kensington, apprenticed with Davey Paxman and Co., Ltd., of Colchester, and subsequently gained experience in the works of Van den Kerchove at Ghent, the old Western Railway of France, and the ordnance department of Sir W. G. Armstrong, Mitchell and Co., at Elswick. In 1896 he joined his father in THE ENGINEER office, and in 1905, at the age of thirty-five, he was chosen to succeed to the editorial chair. He retired in 1946. Those are the facts. But how little they tell us about his life! For it is not the experiences a man has that create his personality; it is what he makes of them. Loughnan was intensely interested in all he saw or heard or read. He found something to learn everywhere. Even at the very end of his life the active, energetic and resourceful mind that inhabited an enfeebled body was still intelligently recording, criticising and comparing the facts and opinions that books and newspapers brought him or the observations of his own eyes set before him. As the body failed, spirit and humour remained indomitable. From boyhood he was accustomed to observe and learn. A strong intelligence permitted him to discover the weaknesses of arguments and theories, and an Irish wit, natural to him, made it possible for him to comment and criticise without offence. It would be interesting to know what impression he made upon teachers such as Silvanus Thompson John Perry and Dr. Armstrong under whom he studied. They certainly made an impression upon him. Some men feel in after life a veneration for their teachers. But his feeling seemed to be one of respectful irreverence! In Belgium and France he undoubtedly learned much practical engineering and acquired a particular interest in locomotives. But he would not have been himself if he had not also learned to appreciate good wine and good cooking! At Elswick, again, his job approached that of what would now be termed a "progress engineer." But it was probably there that he developed a critical appreciation of the merits and demerits of machine tool design, knowledge that he used to the full in later life. Nor did he cease to learn when he joined THE ENGINEER. He learned so speedily and with such a will, indeed, that when his father retired only nine years later he had already acquired sufficient experience to succeed him. For it was only experience he needed. The quality of his mind, its balance, its independence, and particularly its humour had long since fitted him for the post.

So his life's work began. What had gone before had been preparation for it. What he made of it can be seen in the more than eighty volumes that were produced under his superintendence. We might well repeat, as we look at those shelves the great obituary words over the North door of St. Paul's, "Si monumentum requiris, circumspice." His first years in the editorial chair were spent upon the introduction of a number of changes of style and of certain new editorial features designed to improve the appearance of the paper and its real value to engineers. Then the first world war broke out, bringing to him problems with which his father had never had to struggle. Imperturbably he solved them. During that period he undertook to edit, in addition to this journal, *The Ministry of Munitions Journal*, receiving at the end of the war a personal letter of thanks (much treasured) from Mr. Lloyd George. At that period, too, he began and continued into the peace that followed a series of articles which many older engineers will recall, entitled "Random Reflections," in which repeatedly his characteristic wit peeped out. Imperturbably again in the 'thirties he faced the problems and difficulties of the period of the great depression, cheerfully accepting economies and confidently predicting that though volumes must shrink in size for lack of information about engineering activities, sooner or later they would expand again. The outbreak of the second world war found him still in the editorial chair. Though then nearly seventy he remained at his post, attending the office regularly, making light of blitzes, flying bombs and rockets, and carrying on the journal and maintaining its standards despite a staff that became more and more depleted. Only when it was over did he retire remarking that changes would have to be made to modernise the journal and that younger men should take it on; but characteristically showing a deep and constructively critical interest in what his successor proposed to do.



Loughnan St. L. Pendred

But there were two sides to Loughnan Pendred's life, not one. Before the war, at the dinner of the Council Dining Club of the Institution of Mechanical Engineers subsequent to the presentation of a presidential address, it was the custom for menu cards to be printed carrying a humorous cartoon of the president. Mr. Pendred was president of that Institution in 1930–31, and upon the menu he was portrayed double-headed like the well-known advertisement for Shell petrol with the inscription, divided between the two heads, "The Engi——stution." Appropriately enough it expressed the double interests of his life. For if his prime interest lay with the fortunes of THE ENGINEER his desire to serve the Institution came a very close second. He served on its Council from 1920 to 1934. Though dubious of the value of a Charter to the members (he felt the Institution would be less restricted in its actions without it) he still felt it to be an honour to be president in the year during which a Charter was granted it. During his year of office he represented the Institution on the occasion of the fiftieth anniversary celebrations of the American Society of Mechanical Engineers, delighting its members with superb speeches in which profound thought was lightened by the puckish humour and sparkling Irish wit which had already made him famous in his homeland as an after-dinner speaker or, indeed, a speaker upon any other occasion. For invariably he was well worth listening to. The profundity, the wit and the humour are still there for any who care to read—in the Presidential Address recorded in the "*Mechanicals*'" *Proceedings*.

But if the "Mechanicals" came first in his affections, other bodies delighted to honour him in the years between the wars and he was as delighted to serve them. He was a founder member of the Newcomen Society and deservedly twice its president. For he had a wide knowledge and a deep interest in engineering history. His "Eulogy of Richard Trevithick" at Dartford Parish Church in 1933 is still well remembered. He was a

past-president of the Institution of Engineers-in-Charge; an honorary member of the "Juniors," and a member of the Iron and Steel Institute. He served on the Council of the British Standards Institution. In 1934 he was created C.B.E. in recognition of his services to the engineering profession.

Amongst younger men (those now approaching middle age) Mr. Pendred inspired, as one of them has recently expressed it, "Victorian Awe." It is not a term those closer to him would have chosen. For upon repeated contact with him awe soon evaporated and was replaced by deep affection, mixed with respect for his wisdom. Nor was he Victorian. It was to the Edwardian age that he looked back, an age in which the rugged individualism of the early Victorians had been softened by humanism. It is not easy to remember that he was in his forty-fourth year when the *first* world war began! Between the wars he was wholly at home. For, like him, his contemporaries, struggling with the new problems that beset them and which made themselves evident in the General Strike of 1926, the great depression of the 'thirties, and widespread unemployment, looked back nostalgically to the quieter, more secure pre-war days. Being very widely read, as many Victorians and Edwardians were, and possessed of an imaginative intelligence and a gift for writing and speaking, he could express to them their own feelings not only about technical advances, but the way of the world, too. But, even so, the world was already just a little strange to him. He was, for example, keenly interested in wireless. But the interest lay rather in the making of wireless sets in his home workshop than in what wireless brought to him over the air. The activity made up for the fact that his children were now too grown-up to delight in the model railway and other toys he had formerly made for them. He was, too, interested technically, scientifically and critically. But that he was never really impressed by wireless as a means of expression is illustrated by the fact that during the last few years of his life the set was relegated to the kitchen! Again, though he fully appreciated the convenience of a motor-car he never learned to drive.

The second world war brought out in him, as emergencies always did, the very best. But when it was ended he seemed to sense that the world had changed still further and that ideas now current were strange to him and by no means wholly likeable. Not that he ever become "hidebound." It was never a word that could be used of him. He remained intensely interested in the fortunes of THE ENGINEER, of the Institution of Mechanical Engineers, and the world at large, and, as ever, constructively critical of everything done or proposed, or any view expressed, looking forward rather than back. But at home he welcomed with special enthusiasm his son's adoption of angling as a sport and designed and made for him a series of excellent "spinning" reels. There his inventiveness had full play. He had always loved the "White Knight" in *Through the Looking Glass*, and age had ripened his ingenuity. Here was solid familiar ground for the exercise of the skill and craftsmanship he had so long honoured in others.

Now he has gone. Yet however long THE ENGINEER may continue to exist in the future his influence will be felt by those who follow him in its production. He, and his father before him, have created a living and beneficent tradition.

A Memorial Service will be held at The Queen's Chapel of the Savoy on Friday, December 11th, at 12.15 p.m.

Literature

The Resonant Cavity Magnetron. By R. S. H. BOULDING. London: George Newnes, Ltd., Tower House, Southampton Street, Strand, W.C.2. Price 21s.

DR. GRIFFITHS, in his paper "The Development of Radio Valves," read at the Radiolocation Convention of the Institution of Electrical Engineers in 1946, assesses the work on the cavity type of magnetron as "probably the greatest single contribution to radar." Some idea of its importance can be gauged from the fact that the resonant cavity magnetron will give peak output powers of the order of megawatts at frequencies of 3000 megacycles per second, whereas the maximum power previously attainable at these high frequencies was of the order of watts. Articles on the "magnetron" have appeared in technical journals and it has been treated in larger books on radar and electronics. The book under review is one of the first exclusively on the subject.

The opening chapter explains the limitations of the conventional triode oscillator and gives an outline of special kinds of oscillators that have been developed to overcome them. Mention is made of the klystron and the Barkhausen-Kurz oscillators. There follows a chapter on basic electronics, which gives the main properties of electrons and explains emission and space charge. The motion of electrons in electric and magnetic fields is then considered. The essential mathematics for this is very clearly, but comprehensively, presented. The summary of the analytical results at the end of the chapter is useful. A chapter devoted to early types of magnetron concludes the introductory part of the book.

In his explanation of the operation of the resonant cavity magnetron the author first of all simplifies the subject as much as possible and ignores the practical complications and difficulties. A clear qualitative picture of the behaviour of the electrons is given with the aid of good diagrams. A second chapter introduces complications due to alternative modes of operation and gives a simplified theory of "strapping." Critical voltages are then considered. The expression for the cut-off voltage for simplified plane parallel electrodes is obtained in the chapter on electron paths: for cylindrical electrodes formulæ for cut-off voltage and threshold voltage are quoted and practical deductions made from them. The practice adopted in this book of obtaining relations in simplified cases, but quoting, without proof, the corresponding expressions in the more complex practical cases, is very satisfactory for a subject of this nature, where the full theoretical treatment is not amenable to normal mathematical analysis. As pointed out, the calculations have to be made by methods of successive approximations, such as the "self-consistent field method" used by Hartree.

There is in a chapter on power output and efficiency a brief mention of transmission lines and the Smith circle diagram for admittance calculations. The Rieke diagram which gives plots of output power and frequency, is then explained, followed by performance charts which take into account load variations. The practical details of how direct-current power and heater power are supplied to the magnetron, and how the output power is taken out by concentric lines and wave guides, are then dealt with. Frequency changes are considered: both unwanted variations due to instability and load changes and intentional changes that can be effected by tuning.

Descriptions are given of constructional details of magnetrons: particularly cathodes, and anode blocks with their associated permanent magnets. Included in this descriptive matter is a brief discussion on waveguides and resonant cavities. It would have been an improvement if these theoretical subjects, together with the transmission line theory included earlier, were all treated together in the first part of the book or in an appendix. The practical description concludes with construction details of some specimen commercial magnetrons. A bibliography at the end of the book gives references to books and technical journals for further information on the magnetron itself and also on allied subjects.

In this short book of 147 pages a very comprehensive account is given of the theory and practice of the magnetron with emphasis on the resonant cavity type. Throughout the explanations are clear and the simple mathematics which has been included assists and does not complicate. Engineers concerned with the production or operation of any equipment using magnetrons and those who are interested in the history and development of this highly important electronic device will welcome it.

SHORT NOTICES

The Design of Valves and Fittings. By G. H. Pearson, A.M.I.Mech.E. London: Sir Isaac Pitman and Sons, Ltd., Parker Street, W.C.2. Price 50s.—Despite the important part they play in plant of all kinds not a great deal of detailed information has been published on the design of modern valves. In this book the author has set out to provide a work of reference on valves and fittings of many kinds for the use of industrial designers, users and students, and most of the information is based upon his own experience. The book opens with a brief historical review of valves, and then goes on to deal first with cocks as the simplest type of valve. Screw-down stop valves as the most generally used class of valves are next dealt with in great detail in three chapters covering their seatings and bodies, actuating screws and bolted covers. Subsequent sections of the book describe the design, construction, selection and operating considerations of parallel slide valves; safety and relief valves; non-return valves; reducing and surplus valves; hydraulic stop valves; wedge-gate sluice valves; equilibrium float valves; gearing for manually operated valves; valve chests, &c. The text is presented in a clear, concise way and is well illustrated by numerous drawings and diagrams, and includes many useful tables.

In his preface, the author states that "engineers will not require enlightenment as to what is meant by a valve. What they may require, perhaps, is enlightenment in the underlying principles of design and the function of some particular type." We think that in this volume he has provided the means of such enlightenment over a very wide field.

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Basic Engineering Metallurgy. By Carl A. Keyser. London: Macdonald and Co. (Publishers), Ltd., 16, Maddox Street, W.1. Price 60s.

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Relaxation Methods: A Retrospect*

By SIR RICHARD SOUTHWELL, M.A., LL.D., D.Sc., M.I.Mech. E., F.R.S.

IT is more than eighteen years, now, since the notion occurred to me of a procedure which I termed "Systematic Relaxation of Constraints," more than sixteen since I realised that structural frameworks were only the most obvious of the problems to which that device could be applied; and throughout those years—or as much of them as was left to my own disposal—I have been occupied almost incessantly with the question, what in fact are the limits of its range and power? I must therefore face the possibility—nay, the likelihood—that by now I am obsessed by one idea.

I cannot expect again to enjoy the thrill of unexpected progress which all of my small team knew in the busy war years, when problems we had formerly thought intractable yielded, one after another, to our attack. But I can take pleasure in watching the advance continue—especially when our methods are applied to problems that we ourselves could not have contemplated; and you may perhaps find some interest in a survey from that standpoint.

It is wiser, they say, for a lecturer to assume too little than too much, and I shall suppose that even my title calls for explanation. What are relaxation methods? Why was the name adopted? What is their essence: how do they differ from other computational methods? I will try to give simple answers to all these questions.

[Here the lecturer gave examples of problems recently tackled by relaxation methods—including Saint-Venant's torsional problem and the torsional problem as altered by yield.]

The Relaxation Process

Having shown that relaxation methods have some value, let me go back to the questions that I undertook to answer. What are they? Why was the name adopted? What is the essential feature that makes them different?

The name is merely a convenient abbreviation of the full title—"Method of Systematic Relaxation of Constraints"—that I used when I first applied it (in 1935) to structural frameworks. I saw that any set of assumed displacements could be maintained by an application of constraints, or jacks, and that the true displacements—for specified external loads—would be attained if the jacks were systematically "eased away." Attention would then be focused on the forces taken by the jacks, which accordingly would be the criterion of error; and the true displacements would be reached by a tentative but systematic procedure of which every step can be reproduced in calculation. By that line of thought I was led to devise a computational technique which is like the techniques of filing or hand scraping to a template, in that it consists in a systematic removal of unwanted errors; whereas orthodox mathematics, in this analogy, is an elaborate machine whose function is to yield some wanted solution straight away. That is the essential difference as I see it.

I will illustrate by a very simple problem—of a sort we learn to solve while still at school. Below there are two simultaneous equations, and both the orthodox and the relaxational approach are given. I want you to notice the feature that I have said I believe to have been an innovation: namely, the concentration of attention, not on the "wanted quantities" (x and y), but on errors (F_1, F_2) which the table defines and which I term "residuals." We keep account throughout of x and y (in the left-hand column); but it is on F_1 and F_2 that we fix attention—we try to bring both to zero. That is the feature that I see as essential.

"Orthodox" and "Relaxational" Solutions of Two Simultaneous Equations.—To solve the simultaneous equations

$$\left.\begin{aligned} 2x+3y&=0 \quad \text{(i)}\\ 8+6x+13y&=0 \quad \text{(ii)}\end{aligned}\right\}$$

(A) Orthodox approach: multiply (i) by 3 to obtain

$$6x+9y=0 \quad \text{(iii)}$$

and subtract (iii) from (ii) to obtain

$$8+4y=0, \text{ whence } y=-2$$

Then substitute for y in (i) or (ii) or (iii) to get $x=3$.

(B) Relaxational approach: replace (i) and (ii) by

$$\begin{aligned} F_1 \text{ (say)} &= -4(2x+3y) \quad =0 \quad \text{(iv)}\\ F_2 \text{ (say)} &= -2(8+6x+13y)=0 \quad \text{(v)}\end{aligned}$$

and trace the effects of changing x and y severally.

(*a*) For $\Delta x=1$, $\Delta F_1=-8$, $\Delta F_2=-12$
(*b*) For $\Delta y=1$, $\Delta F_1=-12$, $\Delta F_2=-26$

Now take any starting solution and "relax" by (*a*) and (*b*).

	F_1	F_2
For starting solution $x=y=0$	0	−16
(*i*) Use operation (*b*) with $\Delta y=-0{\cdot}5$	6	13
After (*i*)	6	−3
(*ii*) Use operation (*a*) with $\Delta x=1$ ...	−8	−12
After (*ii*)	−2	−15
(*iii*) Use operation (*b*) with $\Delta y=-0{\cdot}5$	6	13
After (*iii*)	4	−2
(*iv*) Use operation (*a*) with $\Delta x=0{\cdot}5$	−4	−6
After (*iv*)	0	−8

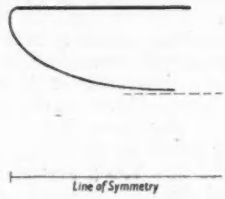
Of course, when the problem is as simple as this there is no case for departing from the method learned at school. It is direct, it is exact, and it is easy: that is, the "machine" is simple. But suppose now that the number of simultaneous equations is not 2 but 10, or 100, or 500 (as it is in some of my illustrations). Then, though the orthodox method is still direct and exact, no one could call it simple and easy to use. Moreover, it has snags!—the machine should yield what is wanted (it was designed to do so), but occasionally it fails. That is where, in the workshop, we have recourse to tentative methods like hand scraping; and in the same way relaxation methods—though in this problem pedestrian and laborious—come into favour where orthodox mathematics lets a computer down.

The "Margin of Uncertainty"

That in this instance the method yields an exact solution is a consequence of the simplicity of the problem, and not important: normally, some residuals will remain, however long computation is continued; a relaxational solution is not exact. (Here my workshop analogy breaks down: for while hand scraping is not exact, neither are machines, whereas orthodox mathematics does yield exact results—when it yields any. For it often fails in a way that is far more serious to a man that must have results—that is, to the engineer; because what it can do in respect of shapes like circles or rectangles—and sometimes, for no reason that makes sense to him, in respect of "weirder" shapes like the cardioid—it all too often fails to do in respect of shapes that interest him—for example, shafts with keyways.)

But for the moment I am concerned with accuracy. We have all, at some time or other, been examinees, and some of us have observed in examination questions a feature that has no counterpart in practice, namely, that while an approximate answer will suffice (that is to say, "the candidate may use a slide rule"), the data—scantlings and loads, in a structural problem—are given as though the examiner knew them exactly, had them by supra-natural inspiration. In practice, loadings are never certain, so problems are never confronted in this form. Dead loads are seldom known within 10 per cent. Wind loads are, normally, mere guesses.

Yet these, in structural problems, are the constant terms in our equations: uncertainty regarding the value of any one of them is uncertainty regarding one of the residuals which we seek to "liquidate" (bring sensibly to zero)! Therefore, I say, not only is it a waste of time, but meaningless, to strive for an accuracy greater than the data will permit. When every residual has been brought within the relevant "margin of uncertainty," further relaxation is as likely to give a solution farther from, as a solution nearer to, what we want. And this is as true in physics as in engineering: there, too, the data, since



(Reproduced from Lamb's Hydrodynamics, p. 98)

Fig. 1—Free Stream-Line for Borda Mouthpiece

they are based on experiment, will always have some margin of uncertainty—small or wide.

The Value of Plotted Diagrams

If you accept this view you will agree, I think, that exactitude is a will-of-the-wisp not worth pursuit by a man whose problems arise in engineering, and that it is his (not the computer's) business to decide what accuracy will have value in any instance. In our working of problems that we formulated we answered that question by imposing a criterion of our own, namely, at least ten times the accuracy which can be utilised by a draughtsman deducing contours from our results.

You will find, as I hope and believe, some measure of æsthetic satisfaction in the contours which present our relaxational solutions. That I attribute to the accuracy of their plotting—and this, in its turn, to the fact that we computed so many values. It is here that "relaxationists" find compensation for the fact that their methods lack the æsthetic appeal of "real" mathematics. Whether the compensation is found adequate depends on whether interest centres in methods or in results. For the mathematician, "To travel hopefully is a better thing than to arrive." But an engineer asks, "Was the journey really necessary?"—and is not so certain, always, about the arrival.

For the sort of solution that orthodox mathematics gives him is exemplified by Fig. 1. Here is the "classical" solution as given by Lamb for a "Borda mouthpiece" through which water issues from an infinite container. It is elegant, it is exact, and

* Abstract. Fortieth Thomas Hawksley Lecture, Institution of Mechanical Engineers, London, November 20th.

(as it stands) it tells him nothing : because, if he really has interest in the problem, he wants to know what the streamline pattern looks like. In other words, he wants plotted contours of the kind that Miss Vaisey obtained by relaxation, and which Fig. 2 exhibits. Lamb, as you see, makes concession to human frailty by showing him just one contour—the " free " streamline. Normally, those who use classical mathematics hardly ever include illustrations in their papers.

I have read that Professor Runge, of Göttingen (a mathematician with an engineer's outlook) used to remark, in this connection, on the " inborn laziness of mathematicians." That I think hardly fair, because the mathematician subscribes to a different creed. The point I want to make now is that such contours as I show could be derived from a classical solution (when one exists), but at far greater cost in labour than by relaxation, starting from scratch.

You will appreciate the flexibility of a method which permits reduction of the mesh size (interval) in those regions where fine detail is important, but only there. " Graded nets " were employed by Miss Vaisey in a number of " free streamline " problems [some of which the lecturer went on to show].

Use of Approximations in Finite Differences

But my worked example concerned algebraic equations—a sort that we learn to solve while still at school ; whereas slides like these are concerned with differential equations involving two independent variables. Do these not call for more elaborate techniques ?

No : because the first step in every instance is to replace the derivatives by approximations in finite differences. Numerical methods cannot determine a function everywhere, any more than every point can have its altitude determined in a geographic survey. Life is too short : we have no option but to use a " net," and for work on nets an obvious technique is provided by the Calculus of Finite Differences, whereby derivatives of a function are expressed in terms of the values which it takes at nodal points. These values then become the wanted quantities, their number N being finite though, when the net is fine, it will be large, and N algebraic equations have to be satisfied, in place of the differential equation which had to be satisfied at every point. Thus modified, every problem reduces to a set of simultaneous equations.

All of this seemed so obvious when I first moved on to differential equations (in 1937) that it did not occur to me to give detailed references ; but I came to regret that I had not done so, because some readers seem to have concluded that use of finite differences was a feature I claimed as new. I use this occasion to make an explicit disclaimer : Finite differences date back to the days of Newton's " fluxions " and Leibnitz's differential calculus, and I used them as I would use any well-established technique. What I thought and still think to have been

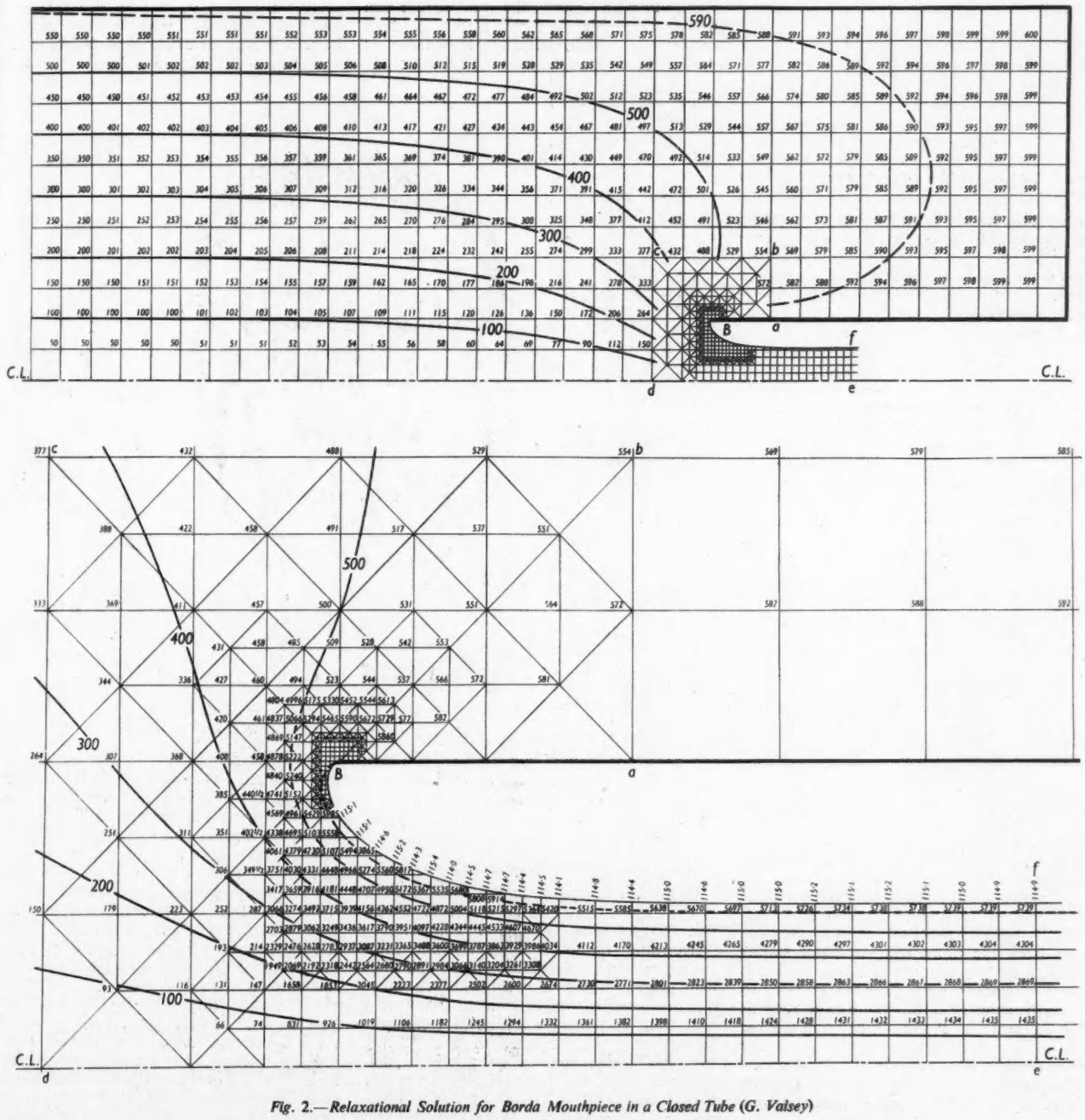


Fig. 2.—Relaxational Solution for Borda Mouthpiece in a Closed Tube (G. Vaisey)

an innovation is the step I call the " relaxational transformation," whereby the computer's attention is focused on the errors.

It would indeed have been preposterous to claim as new a technique what had already been applied as I applied it (i.e. to numerical computation on a net of discrete points) by Runge (1908), Richardson (1910), and Thom (1928)—to name but three. I would mention more particularly the work of Liebmann (1918) with which I was not acquainted when I started. Then, there was only one technique which I would term " relaxational " : the Moment-Distribution Method of Professor Hardy Cross (1924).

Relaxation as Compared with Liebmann's Method

I go on to describe the Liebmann method, since I want to make clear in what respect I think my methods differ significantly. It is in a strict sense iterative—a routine process is performed again and again ; and it

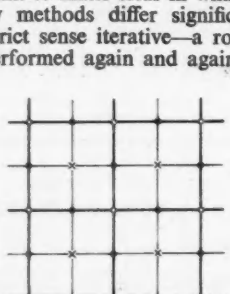


Fig. 3—Liebmann's Method Using Interlacing Nets

fixes attention not on the errors but on the function whose values at the nodal points are wanted. Suppose, for example, that the problem is governed by a plane-harmonic equation : then Liebmann, using two interlacing nets (Fig. 3), starts from a trial solution (guessed values at the nodes of the bold-line net) and systematically deduces, from the finite-difference equation, a value for the centre of every square. Such centres are nodes of the other (fine line) net : so the process can be repeated, and this time it yields new values replacing those from which it started. It can be shown that if continually repeated it will yield solutions which converge.

To see how the relaxational alternative differs, imagine that we face the practical problem of levelling a rough piece of ground to form an air-strip or a sports field. Using Liebmann's technique, we peg out two interlacing nets and then, having determined the heights of the four corners of any square, bring its centre to the mean level of the four ; treat the next square similarly ; and so on. As I have said, the process can be shown to converge—that is, our ground will ultimately be levelled ; but if all four corners were initially too low, then we shall make the centre too low as well, even though this entails removal of material which we shall have to put back later. The treatment is effective, but it wastes labour : inevitably, since no principle enables us to concentrate on those parts of the field that most need attention.

By contrast, adopting Relaxation Methods we should use a sort of dredger or " bulldozer " whose function is to excavate earth from the point over which it stands and deliver it in equal quantities to the four surrounding points (or, in reverse, to lift earth from these four points and deposit it at the centre). Plainly, a cunning worker will not use this blindly, but with an eye to the whole strategic position : some points yield bigger dividends than others—namely, points where a heap is surrounded by four depressions. Working at such points we make five improvements simultaneously, whereas Liebmann's procedure, as I have here described it, may actually make things worse before it makes them better. The end is the same, but relaxation attains it sooner : because it calls for initiative, leaves the next step to be decided by the computer.

And more can be done, for there are relaxational procedures which could be described as more elaborate " bulldozers "—machines that can lift earth from a whole patch of squares and dump it outside that patch, where it is wanted ; and other devices, like " over-relaxation," in which for a time we discard the standard rules since we know that benefit will accrue later. Relaxation is no blindly iterative process : it is a practical craft. To watch a skilled " relaxationist " at work (and I do not claim to be one) is like watching a master-craftsman in some practical art—a jeweller or watch-maker or glass-blower ; for all of them, as we say, " think with their hands "—meaning that all rely on unformulated experience. Closer still, perhaps, is the similarity with design—the best word I can find for that highest manifestation of engineering in which scientific knowledge is applied by an exercise of art ; and I stress this last analogy because, as I believe, it is a feature of relaxation which has real value, that its mode of thought so closely resembles that of a designer. It enables design and computation to proceed, so to speak, hand-in-hand.

The question, how best to train engineers in mathematics, has been debated (I think you will agree) *ad nauseam*, and I have no intention of raising it this evening. But I would remark, as relevant to my theme, on the difficulty engineers experience when they try to formulate problems in a way that suits the thinking of professional mathematicians. The latter want a " sufficient " statement of a problem : that is, equations known to have a solution and enough conditions completely to determine it. But the engineer does not think like that : you can extract a sufficient statement by interrogation, but he will not always produce one, left to himself. For this reason, I say, he wants computers near to him.

Relaxation and Digital Computers

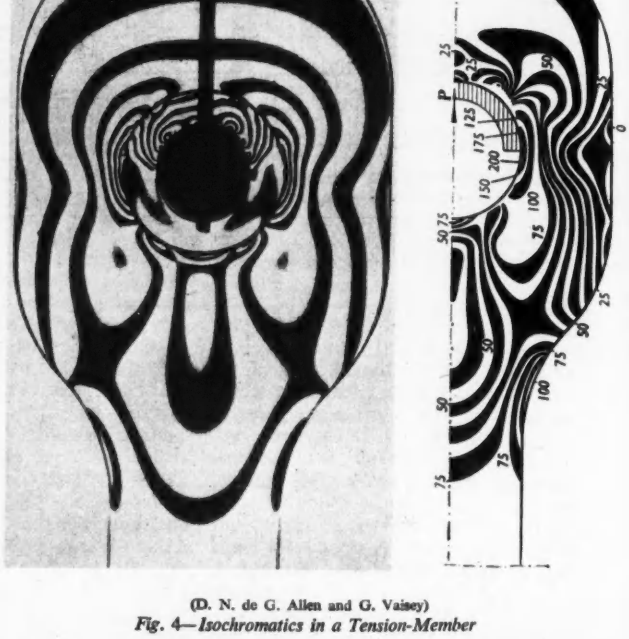
In the last few years, under stimulus given in the 1939–45 war, we have seen an extensive development of digital computers—" electronic brains." Sooner than most engineers appear to realise, most countries will possess these magical aids to computation ; and it might seem to follow that relaxation is merely an interim technique, found useful in the time of our waiting for their completion. I do not hold that view : and not, as I hope to show, because I believe them to be rivals—or even competitors—of relaxation. I believe the two developments to be complementary, mutually ancillary ; and my main reason is the belief I have just stated, that a designer needs to have his computers near him.

First, because in engineering almost every problem is particular. A designer is not concerned to produce a " family " of dams, or aeroplanes, or engines, in which one or more parameters take a series of different values. He has already sought—and believes, or hopes, that he has found—optimal values of the parameters for his purpose, and his need now is of particular computations, to discover what performance has been achieved.

Secondly, because computation may suggest that modifications are desirable, and if so, then his interest at once shifts to another—but again a particular—design. Like an army general, he needs freedom to change plans quickly in the light of altered circumstances.

For both these reasons, I say, he needs to have his computers near to him ; and then, as a rule, they will not have direct access to an " electronic brain." Therefore, I think there will always be need of methods which make no demands beyond desk machines (such as Facits, or Brunsvigas, or Marchants) and which—in the hands of experienced computers—can promise a near solution to any problem. Having used them to get this preliminary solution, his computers may see that for an improved solution (to more significant figures, or for smaller intervals) it would be wise to have recourse to a digital computer. Then, I say, the work they have done already will yield returns by showing them how best to state the problem in a way that suits " programming." (They should themselves know enough of programming for this purpose, although they rely on relaxation in their daily work.)

Conversely, they whose main interest is " machines," should, as I believe, acquire some experience of our methods. For a problem before it can be programmed must be solved in outline (that is, unsuspected snags are to be avoided), and when the problem is of a type not met before, then an



(D. N. de G. Allen and G. Vaisey)

Fig. 4—Isochromatics in a Tension-Member

initial "relaxational" study may suggest new lines of attack. As a rule, mesh-size (the smallness of the chosen interval) affects nothing except the labour of solution: every essential feature (for example, a sort of computational instability which calls for reversal of the normal rules) is revealed as clearly on a coarse as on a fine net. Therefore, I would treat machines and relaxation methods as complementary—mutually ancillary: using relaxation to point the way to a solution, and machines—which are incomparably faster but show no spark of human versatility—to smooth trails already blazed.

Thus I said, when I used the analogy of levelling, that Liebmann's procedure—strictly iterative—may sometimes make things worse before it makes them better, and that our methods used with intelligence will lead faster to solutions. But I would not advocate that a machine be instructed to "relax": because for it time is less important, since it does not tire; whereas relaxation would entail far more complex programming. I, if I owned a digital computer, would make it a member of my "team": a member not outstandingly original, but tireless and not opposed to overtime. In particular, I would use it to check solutions that human computers had found but could not guarantee: thereby lessening their labours.

In Fig. 4 I show, compared with a photo-elastic determination kindly made by Dr. Frocht, our solution for the stresses in a tension-member. We chose the problem as typifying a specially difficult class, and pleased by the agreement of our diagram I suggested that it deserved to have equal "glamour." You see how this was achieved.

Conclusion

It is not an uncommon experience, I suppose, to find a lecture "taking charge." Most of this one, when I planned it, was to be—as earlier lectures have been—a presentation of results; but the illustrations have been fewer than I planned, because I have felt impelled to touch on general aspects in what will probably be my relaxational swan-song.

Looking back over what I have read so far, I wondered if my remarks would seem inappreciative of the orthodox mathematics to which numerical computation is an alternative. I think I am not really inappreciative; but although assured of its logical importance I am not so certain that it need be understood by men whose interest centres in results and who see computation, rather, as alternative to experiment. Let me give a single example of what I mean, and suppose that in the manner of Prandtl (1903) we have reduced Saint-Venant's torsion problem, by analogy, to that of computing the small transverse displacement of a membrane attached to a rigid boundary and sustaining a uniform pressure: if we trust our formulation of the governing equation, where from a physical standpoint is the need to prove the existence of a solution? The membrane, if our picture has validity, has a job to do and must do something about it!

I cannot see it as disrespect to mathematics to say that engineers as such have quite different aims and no concern (for example) with existence-theorems, which aim to prove what they already know to be true. For this is not to say that proof has no importance, or that men who pursue pure mathematics waste their time: I am merely saying that axiomatic certainty is possible in regard to statements not incapable of proof. The mathematician aims to make that category smaller: he will not thereby reduce the value of intuitive certainty for men whose first concern is with results. (A runner or jockey knows, though he cannot prove, that the shortest line joining any two points is straight.)

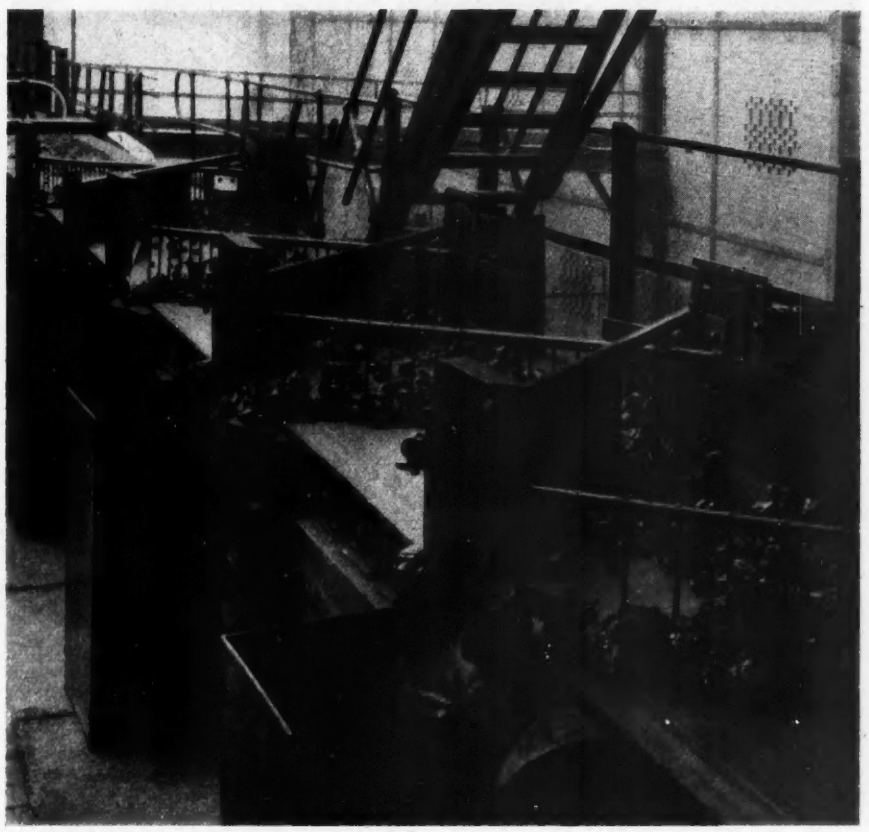
I am wholly convinced that nothing but good will result from a recognition that the aims of mathematics and of engineering are different. If challenged to state the difference I will state it crudely: mathematics rests on æsthetic acceptance of a stringent set of rules: engineering is a rough-and-tumble where "no holds are barred." Relaxation—a mathematics for engineers—adopted that gangster's dictum from the start. It defined its aim—to solve any problem with sufficient accuracy—and when it succeeded it made no apology for its pedigree. Anyone wanting elegance and rigour must look elsewhere!

* * *

Since 1945, at Imperial College, we have offered each summer a four weeks' practical course in which about thirty students work intensively, then go back and preach the new doctrines in their turn. I think the experiment has been successful. It has led to requests from American universities for roughly similar courses—less concentrated, but extending over longer periods. By these and other missionary efforts we have achieved a wide-spread "relaxation-mindedness" in the United States of America and in Belgium, France and Holland; and I was surprised as well as gratified, last winter, to find an equal interest in India. Even so, I believe that many have yet to appreciate the utility of our methods in fields where they could use them but which I, for lack of knowledge, cannot enter. Unlike Alexander who yearned for new lands to conquer, I see new lands but must look to others for their conquest—firmly believing that these methods provide the requisite weapons.

Selective Screen Conveyor

We illustrate below a screening conveyor which has been developed by West's Gas Improvement Company, Ltd., of Manchester, 10, and is designed to combine distribution with screening by progressive elimination without the use of a vibrating surface. As can be seen the equipment consists essentially of a flat band conveyor with a series of comb-like screening units suspended at an angle across the line of travel. These screening units are mounted on flexible supports and are provided with electric vibrators which serve to impart high frequency and small amplitude vibrations. Material passing through each of the screens is redirected to the back of the belt by an inclined cross plate before it passes to the head of the next screen in the line. The smaller pieces of material pass through the vibrating screen arms whilst the larger pieces pass along the line of arms to gravitate down chutes to their respective hoppers.



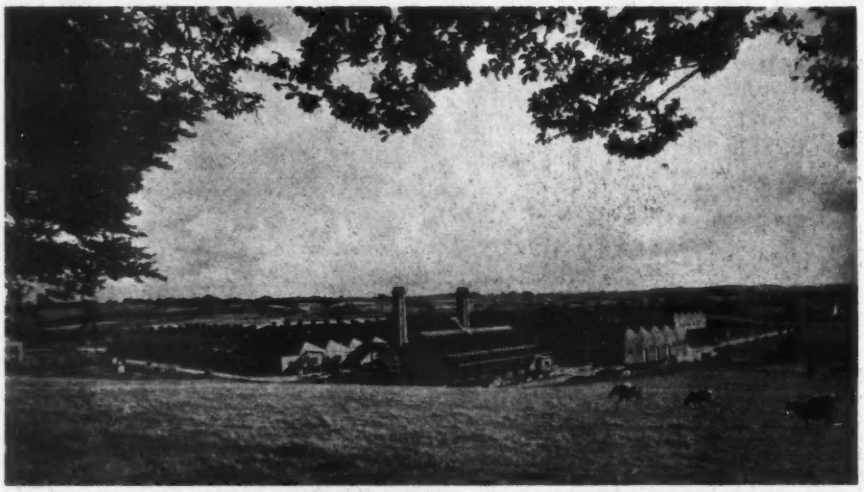
Screen Conveyor

The conveyor grades in descending order of size and the maker points out that this, coupled with the non-vibrating nature of the carrying surface, avoids any appreciable tendency to break the material down. The capacity depends upon the width of the belt conveyor used and the equipment is made in units whereby its length can be readily adjusted in accordance with the particular screening problem. The screening elements are designed for quick and easy changing and they can be varied in gauge to suit size requirements.

Resignalling of Stanmore Branch.—It is announced by London Transport that work is to start next year on a scheme to reduce delays on the Bakerloo Line by resignalling the 4-mile section between Wembley Park and Stanmore. At present any delays which occur, particularly in Central London, cannot be overcome by retiming trains between Wembley Park and Stanmore as the signalling on this section only allows for a three-and-a-half-minute headway. The signalling system to be introduced will permit a two-minute headway. The work coincides with the provision of additional tracks to ease the bottleneck north of Wembley Park where Bakerloo trains now share tracks with Metropolitan stopping trains.

Factory for Turbo-Jet Engines

WE were invited last Friday, in company with Government officials and representatives of the armed Forces and other guests of Rolls-Royce, Ltd., to attend the opening ceremony of a factory at East Kilbride, near Glasgow, for the manufacture of turbo-jet engines. The factory, which was formally opened by the Minister of Supply, the Rt. Hon. Duncan Sandys, forms part of the expansion programme to produce the Rolls-Royce "Avon" engine.



East Kilbride Works for "Avon" Production

The factory (illustrated above) forms an important part of the new township of East Kilbride, designated as one of the twelve new towns in the 1946 New Towns Act.

The factory consists basically of four workshops parallel to each other and separated by roads with grass verges. The canteen and welfare hall is situated on a separate island site adjacent to the factory.

Annexes to the workshop buildings run the full length of each block to accommodate, as near to the production area as possible, ancillary services required by machine and assembly shops. These services include reconditioning of tools, sub-standards room for checking gauges, drawing stores and equipment stores as well as works supervisory offices and progress offices.

The four main blocks contain the machine shops, assembly shops, process plant and stores. The factory is fully tooled for production and the machining of parts began twelve months ago.

Process Block.—The process block houses the heat-treatment department and is equipped with hardening furnaces, tempering furnaces and incandescent gas carburising plant. The large heat-treatment furnaces are loaded and unloaded by means of an automatic furnace charger. The gas carburising plant is of modern design and can carry out carburising without any scaling. As it does away with the necessity of packing components in boxes along with charcoal, the heating cycle is much reduced and the amount of labour required to operate the equipment is also similarly reduced.

The plating shop is equipped for cadmium, copper and chromium plating; anodising, caustic and electrolytic etching; dichromate treatment for magnesium castings, pickling and electro-polishing. The tool room in the same block is equipped with Pratt and Whitney and Oerlikon jig borers in addition to other machinery of the latest design, and it has a standards room.

Machine Shops.—The two centre blocks in the factory are laid out as machine shops. They contain general-purpose and special-purpose machines such as multi-spindle drills, several to the company's own design, for the manufacture to high precision limits of components ranging from small nuts and studs to compressor shafts which are machined from solid forgings, each weighing originally 4½ cwt.

One of the few interesting details in the production of components and blades of which mention can be made relates to the machining of this shaft. It is of steel of the order of 300 tons tensile quality, and the company has developed a tool rig using liquid CO_2 as the cooling agent, which is passed either through the tool body or the tip. With a given feed speeds can roughly be doubled.

Engine Assembly and Repair Shop.—The fourth block is laid out for the assembly and repair of engines and it houses a number of specially designed dynamic balancing machines.

Engine components are built on suitably arranged stands and sub-assemblies are then passed to the erecting line for fitting to the engine which is moved along the assembly line as the work progresses.

To facilitate erection Rolls-Royce, Ltd., has developed a hydraulic platform upon which the engine is assembled in the vertical position. As assembly proceeds the platform is lowered into a pit, so that the most convenient working height at any stage can be selected.

All the workshops are illuminated with cold cathode tube units at roof level giving 40 foot-candle illumination at bench level and making unnecessary the use of local lights on machines, benches and inspection tables. This ensures that the same standard of illumination is used for manufacturing parts as for inspecting them.

Conveyor System.—As the parts for jet engines are produced in relatively small batches, it is not expedient to handle material in large quantities as in factories using mass production methods. Consequently, to reduce handling costs to a minimum a continuous dragline floor conveyor has been installed, having a 1½-mile total circuit.

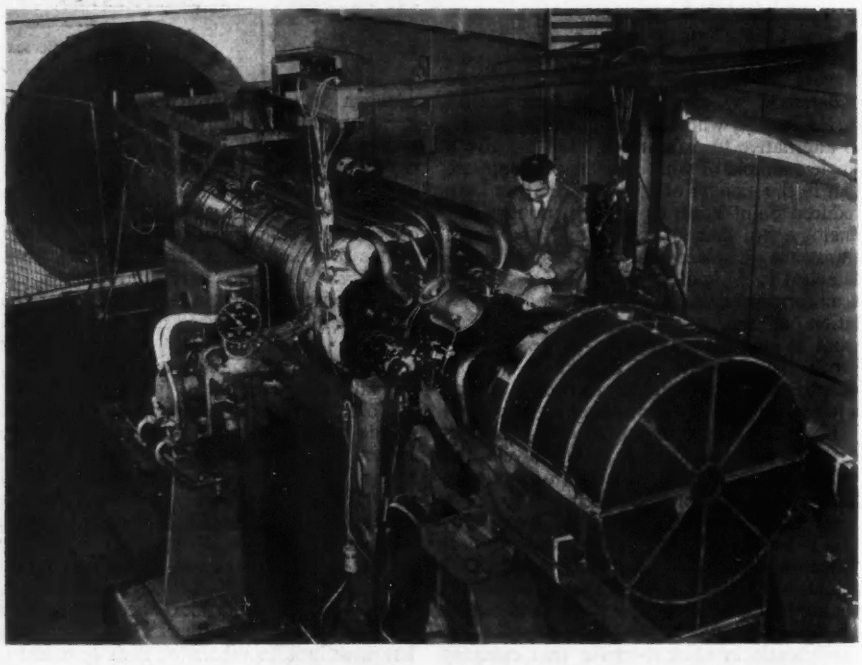
The conveyor consists of a chain running below floor level with pusher plates at 10ft intervals to which trucks can be quickly coupled for dispatch to other departments. A signalling device on each truck enables the destination to be preselected, and also indicates the arrival of the truck at its destination.

The conveyor is used for the issue of materials to machine and process departments, the transport of all part-machined components between blocks and the transportation of finished parts to the stores. Where the conveyor enters or leaves a block, there are sliding guillotine double doors forming an air lock. The doors are automatically lowered and raised as each truck approaches, one door shutting before the other opens.

Engine Testing.—The engine test facilities have been built within the East Kilbride area, but 2 miles from the town to avoid noise disturbance to residents. One bed is shown in our illustration and is similar to those described in THE ENGINEER, May 8, 1953.

As there was insufficient time to visit the test beds a television and sound link was arranged between the beds and the main building.

Two cameras were used at the test beds, and the pictures were transmitted from a 30ft radio mast fixed on the roof of the test beds and received by another 30ft mast on the roof of the canteen. The presentation c.r. tubes were 30in in diameter. All the equipment was supplied by Pye, Ltd. The tour of the factory was controlled from a control room using guides at check points equipped with portable transmitters and receivers.



Engine Test Bed

Shaft Sinking Accidents, 1905-'52

EXPERIENCE WITH CAST IRON LININGS IN COMPRESSED AIR

By IAN C. EASTON, B.Sc., A.M.I.C.E.

THE accompanying table and diagrams give particulars of shaft sinking accidents due to the fracture of cast iron in tension. The first accident was regarded as exceptional, but in 1909 several engineers said it drew attention to the unreliability of cast iron and the firm concerned have since made a practice of using all-steel cylinders. The next two accidents in Wallsend appear to have been accepted as unlucky strokes of fate. At the Deptford inquiry, however, H.M. Inspectors, after investigating other possible causes, such as an old enemy bomb, ignition of the lubricating oil or of a combustible substance or the presence of hydrogen or methane gas, found that "certain parts of the material were subjected to a very much greater stress than had been supposed, a stress which it was not safe to put upon cast iron in tension. We conclude that this mass of cast iron broke because it was not strong enough to withstand the stress." Another fatal accident occurred in a cast iron shaft at Point of Ayr Collieries, Flintshire, on July 4, 1952. The purpose of these notes is to draw attention to the dangers in the hope that such accidents may be avoided in future.

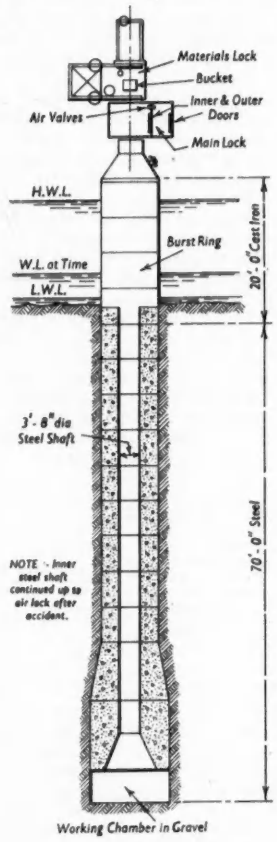


Fig. 1—Suir Viaduct

Except in the first case, the method of construction was underpinning. This method requires better strata than is required for a caisson or cylinder because :—

(*a*) A length of 18in to 3ft has to be excavated at the bottom for each ring and (unless a shield is used) must stand with little or no support until the ring is built and grouted complete.

(*b*) The lining depends for its vertical support upon the skin friction between the outside of the lining and the ground.

(*c*) The volume to be maintained under compressed air and the air pressure both increase as the sinking proceeds. At the top of the shaft the internal pressure therefore becomes much greater than the external pressure (if any).

The fact that other shafts have been sunk successfully under apparently similar conditions may be misleading. There may be no margin of safety even though it has been done before in similar circumstances. Theoretical calculations are of little value. The wide variation in the stresses in the table should be noted. It arises largely because the assumptions made are inadequate. Stresses are not uniform or simple and are concentrated near bolts. Flanges give neces-

6in wide test pieces failed under loads of 3 and 4 tons at bolt hole, i.e. only twice actual load if uniform around circumference.

Total upward pressure
$= 13 \times 10^3 \times 12^2\pi/2240 = 250$ tons
Weight of deck, &c.... 50
Net vertical up-thrust = 200 tons

Most of this 200 tons was taken by main girders in addition to direct tension, load on main girders caused a bending moment at *P* (Section XX) excessive stress near end of main girder caused failure which spread rapidly round removing roof as if cut off by a tin opener.

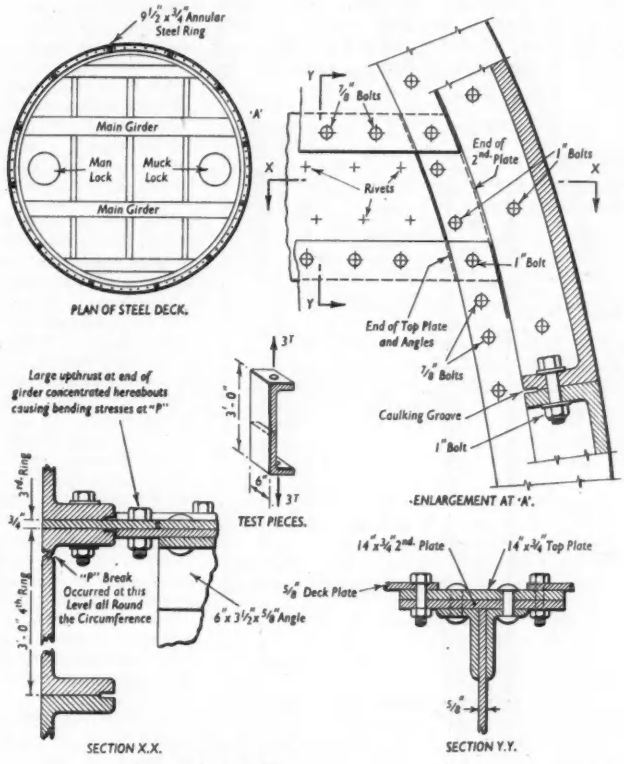


Fig. 2—Deptford

Summary of Shaft Accidents Due to Fracture of Cast Iron

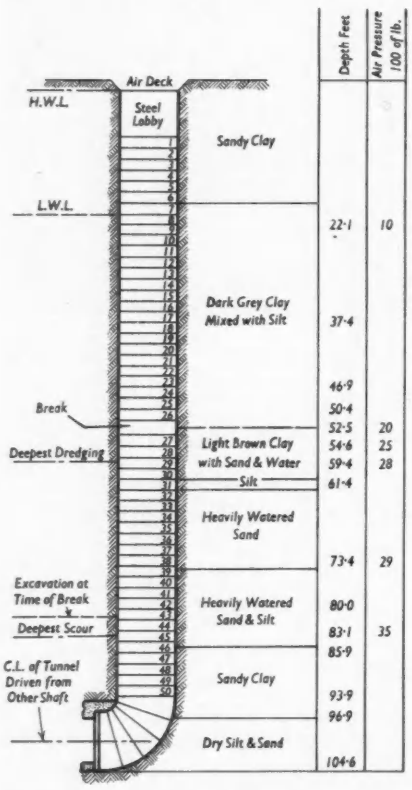
Place	Year	Number killed	Air pressure, lb/sq. in	Strata at top of shaft	Method of construction	Nature of main bursting force	Diameter of shaft	Thickness of cast iron	Theoretical tension, lb/sq. in.	Remarks	Authority
Suir Viaduct, Eire (Fig. 1)	About 1905	1	32	Mud	Cylinder or caisson	Hoop tension	7ft 9½in	1¼in *	1200	17 other cylinders. Some a similar depth. Broke just above ground level	Inst. of Engineers and Shipbuilders in Scotland, Vol. 52, page 82
Wallsend tunnel	1907	1	28	Not known	Underpinning	Probably hoop tension	10ft	Not known		Victim on surface. No one down shaft ?	*Newcastle Daily Chronicle*, November 19, 1907
Do. (other side of river)	1908	1	Reduced at the time	Running sand on one side		Hoop tension	10ft			3 men blown up shaft	*Newcastle Daily Chronicle*, August 21 and 24, 1908
Deptford Green (Fig. 2)	1927	5	13	Made-up ground	Underpinning	Vertical upthrust	20ft	1in	600 (if uniform)	Another apparently similar shaft sunk successfully before	Home Office Report, No. 1853, and template
Hooghly. River, Calcutta (Fig. 3)	1930	—	33 (31 after accident)	Clay above break. Wet sand and silt below	Underpinning (using a shaft shield)	Weight of lining unsupported by ground	About 8ft	¾in	1785 (if uniform)	Circumferential break and 5in drop well below ground level*	Inst. C.E., Vol. 235, page 290. Paper by Lieut.-Col. C. M. Norrie, D.S.O., B.Sc., M.I.C.E.
Point of Ayr, Flintshire	1952	6	35	Alluvium	Underpinning	Do. do. and/or hoop tension	About 18ft	1in	Hoop tension about 3600 (if uniform)	Broke just below concrete block, i.e. near ground level. Over 30ft of running sand	Inquest Proceedings. *The Colliery Guardian*, August 20 and 27, 1953

NOTE.—Five times the break occurred at or near top of shaft, where external pressure (if any) is lowest.

* Second shaft sunk driving shield through annular ring of clay placed in pockets below cutting edge. Lining suspended from air deck by rods.

sary stiffness and rigidity, but introduce severe torsion and bending moments. Unequal tightening of bolts holding different segments and rings together can cause further stresses. Air leakages through the soil may create soft pockets behind the lining and (in and near air locks) sudden and repeated temperature changes may introduce further indeterminate stresses at joints. Flanges also make segments more complicated to cast and cause cooling stresses. Nor can hoop tension and vertical upthrust normally be isolated. The combined effect of both stresses in the curved skin of the lining must be considered.

If the shaft is sunk as a caisson or cylinder a steel or solid concrete deck will be required above the working chamber. Steel shafts should lead from this deck to the air locks, which must, of course, be above high-water level. If the shaft is sunk by underpinning,



Broken rings 27 and 28 replaced and gap (finally 2ft) made good with special casting.

Fig. 3—Hooghly River

adequate kentledge or dead load should always be provided with a reasonable safety margin above the net upthrust of the air pressure. (It is, of course, necessary to ensure that the roof or deck is capable of taking this load if the pressure is reduced or removed altogether.) If a steel deck is used care must be taken to ensure that the joint between the steel and the cast iron (if used) is of ample strength. If the roof is in reasonable ground which can safely be relied upon to resist the maximum internal pressure, a cast iron or concrete-lined shaft may be used with a thick concrete deck. If the ground cannot be relied upon, then steel bands may be used outside the cast iron rings. Alternatively, circumferential steel rods encased in concrete may be used inside the cast iron lining. When sinking through a great thickness of running sand, it is difficult to keep the bottom dry without losing air near the top of the bed. Special precautions were taken in the second Hooghly River shaft, but it would appear to be easier and much safer to use a caisson or cylinder.

The best method of all is to give up cast iron altogether and use structural steel shapes or cast steel instead. This is expensive, but the author understands that it is now the practice in the United States and on the Continent.

Recent Progress in Soil-Cement for Road Construction*

By D. J. MACLEAN, B.Sc., A.Inst.P.†

In recent years, and particularly in the last twelve months, the soil-cement process has made encouraging progress as a means of constructing road foundations, and it has been demonstrated both by laboratory investigations and by practical experience that a wider variety of soils can successfully be treated than previously appeared likely. We are in sight of the production of British plant, the prototype of which has demonstrated that it is at least equal, if not superior, in performance to any other plant designed for soil-cement construction.

As a result of recent progress in its development, it is considered to be fair to say that soil-cement has become potentially the most important method of constructing road foundations, and the process that offers the principal means of effecting substantial reductions in the costs of new road construction. In spite of the progress already made, the soil-cement process is capable of considerable further improvement, provided that the necessary effort can be made available for research into soil-cement as a material and into the development of plant.

The soil-cement work carried out in the past in this country has been confined largely to granular soils ; although in the U.S.A. it has been found that cohesive soils with liquid limits as high as 40 per cent can be successfully stabilised with cement, there has been some reluctance to treat such soils in this country principally because they are generally found in a wetter condition than in the U.S.A., and it is consequently more difficult to mix the cement thoroughly into the soil. Recent experience on a housing estate road scheme showed that although this difficulty did exist, modern rotary tiller plant was capable in ordinary weather conditions of dealing quite satisfactorily with a clay soil with a liquid limit of about 45 per cent, and it is likely that the new British plant being developed will be able to extend the range of soils to clays with liquid limits in excess of this value.

The development of plant capable of carrying out the stabilisation of clay soils has necessitated investigations to determine whether clay soils can be satisfactorily hardened by the admixture of cement. This problem is fairly complex, since not only do clay particles in a soil consist of a variety of minerals, such as kaolinite, montmorillonite and mica, but the particles adsorb on to their surfaces different ions, such as calcium, sodium and hydrogen. Both the type of clay mineral and type of adsorbed ion influence the stabilisation of the soil with cement.

Considering first the problems arising from the adsorbed ions, these can affect both the hydration of the cement and the ease with which the cement can be mixed with the soil. Three common cases occur :—

(1) Calcium clay soils are easy to stabilise with ordinary Portland cement. There is no interference with the mechanism of hydration of cement, and the soil is easily broken into small aggregations that can be intimately mixed with the cement.

A typical example of a calcium clay soil is the brick-earth soil occurring in the grounds of the Road Research Laboratory ; this soil can be satisfactorily stabilised with 10 per cent by weight of ordinary Portland cement.

(2) Sodium clays are less easy to stabilise because mixing is difficult on account of the deflocculated, and consequently sticky, condition of the clay. To overcome this difficulty hydrated lime has to be added to convert the sodium clay to a calcium clay.

A practical example of this case is the sodium clay at Droitwich, in Worcestershire, where Brooke-Bradley has reported the use of 8 per cent of hydrated lime in addition to cement for its stabilisation.

(3) Hydrogen clays, which usually result from the presence of organic matter in the form of humic acids, do not usually give an adequate stability when treated with 10 per cent by weight of ordinary Portland cement. In this case a large number of calcium ions are removed from the cement through base exchange with the hydrogen-saturated clay particles, with the result that the hydration of the cement is adversely affected. The remedy for this is the introduction of more calcium ions either by using a larger proportion of Portland cement or alternatively a secondary additive such as hydrated lime or calcium chloride.

The effect of the mineral type of the clay fraction in a soil reveals itself in the behaviour of the soil-cement in the presence of free water. From available evidence it appears that cement-stabilised clay soils whose stabilities are similar under conditions of constant moisture content are liable with an inadequate cement content to break up in different ways when brought into contact with water. Thus, specimens of soil containing montmorillonite clay stabilised with 10 per cent of cement have been known to disintegrate with explosive violence when brought into contact with water, while corresponding specimens of cement-stabilised soil containing illite clay disintegrated slowly over a long period of time. This difference is attributed to the different extents to which aggregations of clay particles expand when in contact with water, depending upon the type of mineral of which they are composed. It would thus appear that the less expansive clay soils are more suited to stabilisation with cement.

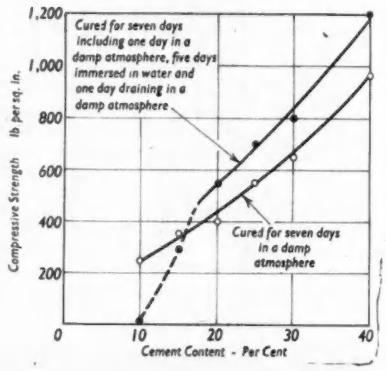


Fig. 1—Comparison of the Effects on its Compressive Strength of Curing Cement-Stabilised Clay Soil Under Water and in a Damp Atmosphere

In Fig. 1 a comparison is made of the relationship between the compressive strength at an age of seven days of a cement-stabilised heavy clay and the cement content for two methods of curing : first, curing in a damp atmosphere and secondly, immersion in water for five days prior and subsequent to a day of curing in a damp atmosphere. While an adequate strength was achieved by the stabilised soil when cured in a damp atmosphere with 10 per cent of cement, complete breakdown resulted from immersion in water. A cement content of 15 per cent was required to give an adequate strength to specimens immersed in water. It thus appears that in order to determine the required cement content to stabilise clay soils a test involving immersion in water should be adopted.

In the case of granular soils the only effect arising from chemical causes is the delay in hardening of ordinary Portland cement caused by heath sands containing organic matter. This difficulty can be overcome by the addition of calcium chloride either in the form of a rapid-hardening cement containing this chemical or by its separate use, in a proportion of about

* Paper presented at a meeting of the Pavings Development Group of the Cement and Concrete Association, held at the Institution of Civil Engineers on November 19th.

† Head of Soils Section, Road Research Laboratory.

1 per cent by weight of the soil, with ordinary Portland cement. The organic matter is thought to delay the hydration of the cement by preferentially removing calcium ions, and the calcium chloride makes good this deficiency.

In Fig. 2 the variation in the compressive strength at an age of seven days is shown of specimens of sand taken from different depths in a profile of heath sand and stabilised with 10 per cent of respectively ordinary Portland cement, a rapid hardening cement containing calcium chloride, and ordinary Portland cement with 1 per cent of calcium chloride added separately. The results in Fig. 2, which are typical of many profiles studied, show that in such cases the ability to stabilise depends critically on the level

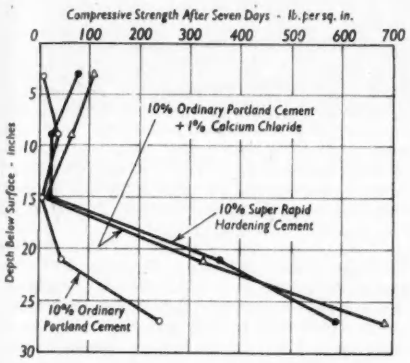


Fig. 2—Variation with Depth of Strength of Organic Sand at Age of Seven Days when Treated with 10 per cent of Three Different Stabilisers

below the ground surface, and it is clearly advantageous to take account of this wherever practical.

By analogy with their effect on concrete, sulphates in soil might be expected to be deleterious to soil-cement. However, laboratory investigations have shown that the presence of a small proportion of sulphate in a soil does not result in a loss of strength in cement-stabilised soil, and no evidence has been noted in this country where soil-cement has been affected after hardening by contact externally with dissolved sulphates from the surrounding soil.

The potentialities of cement ground to a finer condition than that normally marketed are at present being examined at the Road Research Laboratory. In Fig. 3 a comparison is made of the compressive strength at different ages of a sandy clay soil stabilised with 10 per cent of respectively ordinary Portland cement and the fraction of the same cement passing a B.S. 300 mesh sieve. The much higher early strengths obtained with the finer cement suggests that its use might enable lower cement contents to be used to stabilise soils ; it would be interesting to know whether cements of this, or even greater, fineness can be marketed at a reasonable price. Although in this country the increase in cost of manufacture might outweigh the effect of using a smaller proportion of cement, the situation would probably be different in some cases overseas, where the cost of transport is an important factor. The matter is also of considerable interest in relation to military uses of soil-cement. Fig. 3 shows that the strength after one day, given by the fine fraction of cement, is equal to that after seven days given by the normal cement. The use of fine-grained cement is thus thought to offer a basis for a rapid compressive strength test for soil-cement, if a reasonably good correlation between the strengths of soil-cement stabilised with cements of different fineness can be established. This possibility is being explored at the Road Research Laboratory.

The Design of Soil-Cement Roads

A knowledge of the principles underlying the design of soil-cement roads is needed in order to be able to calculate by a rational method the thickness of road structure required and the stability that the soil-cement should possess.

Recent laboratory and field investigations support the view that a road structure incorporating a soil-cement layer probably behaves as a flexible pavement. Laboratory measurements show that the flexural strength of soil-cement is numerically about one-fifth the compressive strength. On this basis soil-cement in normal construction work will usually have a flexural strength at an age of seven days of 30 lb to 40 lb per square inch. Calculations made by means of the Westergaard analysis indicate that this is insufficient to prevent cracking of the soil-cement. Observations have shown, however, that the flexural failure of soil-cement takes the form of closely spaced fine cracks that have little effect on the stability of the stabilised layer.

On the basis of present information, therefore, it appears desirable to calculate the thickness of the road structure by means of a method of flexible pavement design, such as the California bearing ratio method. A small amount of field evidence has, however, been obtained that suggests soil-cement roads can be constructed to a smaller thickness than roads with granular bases, to which the California bearing ratio method is principally applied. A full-scale road experiment has been planned by the Road Research Laboratory, to be constructed next year, to investigate this matter further.

The analysis of the behaviour of soil-cement from a consideration of its flexural strength lends support to the criterion of a compressive strength of 250 lb per square inch at an age of seven days, which has been used successfully for some time to specify the type and proportion of cement required to stabilise soils for road foundations ; the analysis also indicates that higher strengths are not only unnecessary, but probably undesirable, since the flexural failure of soil-cement with higher strengths would result in cracks occurring at a greater spacing ; when this happens in practice it is found to be associated with wider cracks having less adequate interlocking.

The usual practice is to surface soil-cement with some form of bituminous surfacing. Experience has shown that it is essential for the surfacing to be impervious, since the combined action of water and stressing by traffic is liable to soften any weak areas in the soil-cement. For housing estate roads a double surface dressing has proved adequate during the period of the building operations, after which a premixed bituminous surfacing has usually been laid. On

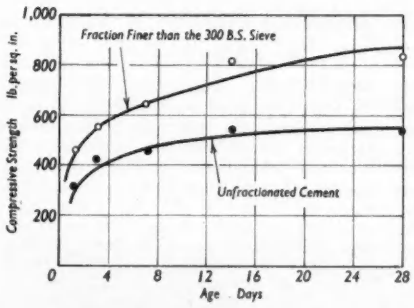


Fig. 3—Effect of Fineness of Cement on the Strength of a Sandy Clay Stabilised with 10 per cent of the Cement

classified roads the usual practice is to lay a two-course bituminous surfacing about 4in thick, and this has been found to be adequate even for main road traffic.

An experiment on a main road is being planned by the Road Research Laboratory, in which the performance of different types and thicknesses of bituminous surfacing will be tested on a soil-cement foundation. An interesting possibility which will be examined in this experiment is whether a comparatively thin single-course dense impervious surfacing is adequate on a soil-cement base for main road conditions. The use of a thin surfacing calls for good levels on the surface of the soil-cement base, but it is a means of reducing the overall cost of construction. In this connection a tarmacadam base course, which on a granular base provides a temporary surfacing while the granular material is being fully compacted by traffic, is not essential with soil-cement which does not compact after it has hardened. The final wearing surface can therefore be laid on the soil-cement immediately after the curing period.

Methods of Construction and Machinery

Immediate developments in the soil-cement process are most likely to result from an improvement in the methods of construction employed, and this in turn is dependent upon the introduction of more efficient types of machinery. Unfortunately, no specialised machines of British manufacture have been available in the past for soil-cement road works, and this has seriously hindered the development of the process in Great Britain. At long last British prototype soil stabilisation machines have been produced, and the marketing of these machines will undoubtedly remove a serious handicap to a more widespread use of soil-cement for constructing roads in this country.

The principal method of construction used in the past has been mix-in-place, although a limited

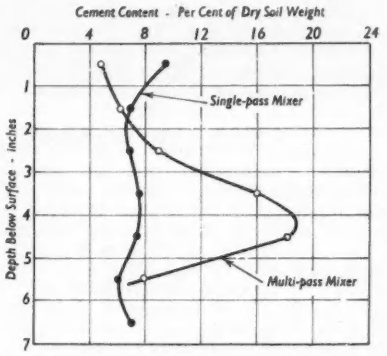


Fig. 4—Comparison of the Variation of Cement Content with Depth Obtained with Two Types of Mix-in-Place Machines

amount of work has been done by the plant-mix method. Each method has its advantages and disadvantages : mix-in-place enables high rates of construction at a low cost to be achieved, but the uniformity of the mixing and of the depth of the stabilised layer are less satisfactory than are obtained with the plant-mix method, which, however, gives lower rates of construction at a higher cost.

Since the main advantage of stabilised soil over other forms of road construction is its cheapness, developments in plant have been concentrated principally on the machines required for mix-in-place work with the objects of approaching the quality of plant-mix work, but at the same time maintaining the rates of construction and low costs normal to mix-in-place work. The developments in plant have been accompanied by field studies by both the Road Research Laboratory and by the Military Engineering Experimental Establishment.

A number of conclusions have emerged from these investigations, of which perhaps the most important is that single-pass soil stabilising machines have considerable advantages over multi-pass machines. An obvious advantage is the ability to start and stop operations as required. This means that work can be confined to a definite number of working hours each day in contrast to operating with multi-pass machines where an over-estimation of the area capable of being processed in a day sometimes leads to the final compaction being carried out late in the evening under difficult conditions. Single-pass machines also virtually eliminate difficulties arising from weather conditions, particularly the onset of heavy rain, since operations can be stopped immediately conditions become unsatisfactory. Apart from these obvious advantages, investigations have shown that, while the distribution of cement in the processed layer of soil has sometimes been very unsatisfactory with existing multi-pass machines, comparatively uniform distribution has so far been obtained with all the single-pass machines investigated. Results illustrating this point are shown in Fig. 4. Although the better results with the single-pass machines are probably due in part to the improved designs of the rotary tiller, other experience suggests that segregation of the cement in the soil increases with the number of passes of the machine and that with each additional pass there is an increased possibility of the soil-cement being carried outside and the

cement below the limits of the planned cross-section of the stabilised soil layer.

A prototype form of single-pass stabiliser of British manufacture has recently been developed that employs a high-speed rotor with milling cutter blades. The high speed of rotation coupled with the comparatively slow forward speed of 2 yards per minute results in the breaking up of the soil to a very fine tilth, thus enabling the cement to be intimately mixed with the soil. Experiments with a silty clay soil showed that this machine gave in a single pass an efficiency of mixing of 66 per cent compared with an efficiency of 48 per cent by eight passes of an American rotary tiller stabilising machine. (The efficiency of mixing is the compressive strength at an age of seven days of the soil-cement processed by the machine expressed as a percentage of the corresponding strength of the processed soil-cement whose mixing is completed in a laboratory mixer.) The efficient way in which this machine dealt with the silty clay soil (liquid limit of 45 per cent) suggests that the machine will successfully process comparatively heavy clay soils without a too serious loss of efficiency.

A dropping-weight compaction machine has been developed to follow the single-pass stabilising machine referred to above. The advantage of compaction by impact is that an adequate state of compaction can be achieved with a wide range of soils over a range of moisture conditions by one pass of the machine ; these requirements are difficult to obtain with other forms of compaction. These conclusions are based on extensive investigations of compaction machines by the Road Research Laboratory and the reasons for them have been developed in detail.

A serious drawback of all existing mix-in-place plant is their inability to process a layer greater than 8in in thickness. Although the construction of a double layer of soil-cement has been demonstrated to be feasible, this reduces the efficiency of the process, and the development of machines capable of treating a depth of 12in is an urgent requirement if soil-cement is to be applied on a considerable scale to the construction of main roads.

Methods of Test for Soil-Cement

Before any construction work with soil-cement is undertaken, an essential preliminary is to survey the soils present on the site and to determine their suitability for stabilisation by means of laboratory tests. The need for this soil testing should not deter road authorities from exploring the possibilities of employing the soil-cement process, since there is no difficulty in arranging for the testing at a cost which is small in relation to the potential saving in the cost of construction. A number of English county highway authorities are equipped with the necessary laboratory facilities and are prepared to examine soils for the small road authority ; there are also firms that specialise in soil testing.

Considerable effort has been devoted to the development of reliable test procedures for stabilised soil. Some of these tests have been standardised in B.S. 1924 : 1953, and a committee of the British Standards Institution is at present engaged on drafting standard methods for the remaining tests required.

The usual procedure followed in examining the suitability of a soil for soil-cement work is first to establish by means of the identification tests described in B.S. 1377 : 1948 that the soil falls into a group that can be satisfactorily processed with available plant, and then to determine by means of strength tests coupled sometimes with weathering tests the proportion of cement, and possibly of secondary additive, required to stabilise the soil satisfactorily.

The principal strength test comprises the measurement of the unconfined compressive strength of cylindrical specimens of soil-cement after curing for seven days at a constant moisture content, but B.S. 1924 : 1953 provides an alternative method known as the cylinder penetration test. This test is an adaptation of the California bearing ratio test, to make it applicable to stabilised soils and at the same time to enable advantage to be taken of the considerable experience of the relation between the results of this test and the performance of road foundation materials in practice. It is known that a satisfactory road base material should have a minimum bearing ratio of 60 per cent, so that, allowing for the lower quality of soil-cement that can be laid in practice compared with that made in the laboratory, it is considered that a bearing ratio of 100 per cent at an age of seven days is a suitable laboratory criterion on which to design soil-cement mixes.

In certain cases it is necessary to examine by means of laboratory tests whether a cement-stabilised soil is liable to deteriorate from the effects of water or of frost. As previously mentioned the effect of water has to be considered where clay soils are being stabilised, and the cement content for satisfactory stabilisation should be that which enables laboratory specimens to maintain an adequate strength when subjected to immersion for five days during the curing period of seven days.

Very few cases of frost affecting soil-cement roads have been reported in this country, and these appear to have arisen from unsatisfactory processing. The available evidence suggests, therefore, that soil-cement is not susceptible to the frost conditions usually experienced in this country. Nevertheless, until more experience is gained, it is desirable to check the frost-susceptibility of cement-stabilised soil where the parent soil is known to be frost-susceptible and where frosts are liable to be severe.

A simple apparatus has been devised at the Road Research Laboratory for studying the frost susceptibility of stabilised soils. A cylindrical specimen of the soil-cement is supported in a " Perspex " frame which can be mounted on a suitable vacuum flask such that only the upper face of the cylinder is exposed and the bottom of the cylinder is immersed in water a few degrees Centigrade above freezing point. The apparatus is placed in a refrigerator maintained at −5 deg. Cent. and any expansion of the cylinder due to the formation of ice lenses is measured with the dial gauge. Negligible expansion of the specimen after a few days under these severe conditions should be a reasonable indication that the soil-cement is unlikely to be affected by frost in practice, but further work is needed to correlate the results of this type of test with practice.

Industrial Progress in China

(By Our Indian Correspondent)

October is the stocktaking month in China, and the State Statistical Bureau of the Government of the People's Republic of China has recently come out with its communiqué on the results of " the rehabilitation and development of the national economy and culture and education in the country in the year 1952–53." The report registers some impressive statistics of production and construction, but they are almost without exception given in terms of percentages which appear to conceal more than they reveal. Reading between lines, however, it is possible to arrive at certain conclusions, namely, the progress is impressive, but not spectacular, and the Chinese, although they do not say so in so many words, would be grateful for some technical assistance from the countries of Western Europe.

The report begins with the industrial sector, in which " production targets of the major products, with few exceptions, were overfulfilled." Pig iron, for example, was fulfilled 111 per cent, steel 118 per cent, coal 106 per cent, crude oil 110 per cent, copper 110 per cent, lead 108 per cent, electric motors 118 per cent, cotton yarn 106 per cent, and cotton cloth 109 per cent. The gross output, in terms of unchanged prices, was some 28 per cent above 1951. Of the total output, State-owned enterprises accounted for 50 per cent of the value, private enterprise 42 per cent, co-operative 3 per cent, and mixed enterprise 5 per cent. The small percentage increases in production are probably due to the fact that the capital construction programme is only just under way. The total capital investment appears relatively large : compared with 1951 the increase in iron and steel industry was 356 per cent, electrical power 400 per cent, cement 251 per cent, and non-ferrous metals 250 per cent. If the figures are reliable, the rate of investment is about five times as high as in India.

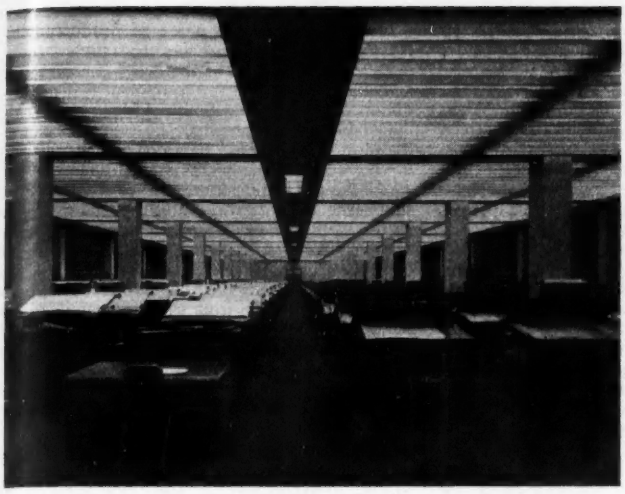
The report then wanders away from the irritating percentages and concentrates on individual industries, although actual production figures are carefully avoided in most cases. Eighty-five major industrial projects are under construction in North-East China, the country's Ruhr. " The main efforts are concentrated on iron and steel, machine building, fuel and power industries, while due attention is given to the textile, sugar, rubber and paper industries." At Anshan, where the country's first automatic blast-furnace began production last year, the new projects include the construction of a heavy rolling mill, a sheet mill and the reconstruction of a blast-furnace, an open-hearth furnace mill and a blooming mill. In the machine building industry eleven factories are being newly built or expanded. They include an automobile factory (whose foundation was laid on July 15th), a precision measuring cutting tool factory, a pneumatic tool plant, and a wire and cable factory. The new machine factory in Mukden will manufacture high-speed heavy machine tools and the pneumatic tool plant at Harbin will produce rock drills, riveting machines, picks and other tools used in building and bridge construction, shipbuilding and mining. The electrical machinery plant at Harbin will produce large and medium electric motors and complete sets of generating equipment.

Construction has started on the 3000km Lanchow-Sinkiang railway through the Gobi Desert in the far north-west. A total of 480km of new railways were built and 742km repaired in 1952. The total railway mileage in China by the end of 1952 was 24,232km, compared with 21,715km in 1949. Two new motor roads, each over 1000km long, are being pushed forward across the Tibetan Plateau. " They will eventually reach Lhasa from the east and the north." This piece of news is entirely convincing, for the flurry of increasing activity on the Indo-Tibetan border has been the subject of a number of questions in the Indian Parliament.

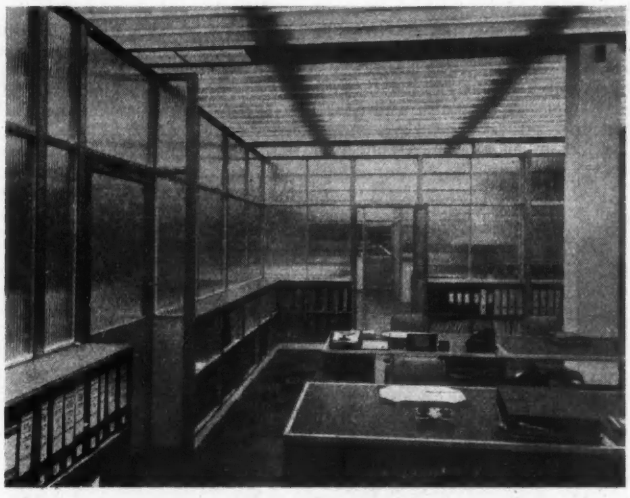
The report then goes on to list some of the achievements in water conservancy work. " All the major rivers, the Yellow River, the Yangtze, the Huai, the Yungting, and the Pearl rivers, have had their dykes overhauled and strengthened in the past four years. By October 1, 1952, the amount of earthwork dealt with on all the water projects equalled twenty-three Suez Canals or ten Panama Canals." This sounds spectacular until one comes to the sentence, " the biggest dam on the Huai River, the 697m long diversion dam, was completed on July 25th." This biggest dam is smaller than nearly every major dam under construction in India to-day. All dams of the Damodar Valley project excepting Tilaiya are longer and higher than the Huai diversion weir. In the field of irrigation a total of 3,300,000 hectares (8,150,000 acres) have been brought under cultivation and a further 2,800,000 hectares will be irrigated this year. No great progress appears to have been made in hydro power. The Yangtze and the Yellow rivers, great potential sources of power, are being surveyed in great detail and a start has been made to link the Tatu and the Mapien tributaries of the Yangtze through a tunnel. These rivers are only 7km apart, but have a difference of 80m in their levels.

The report is full of references to the Soviet assistance and the extraordinary abilities of Soviet technicians. A typical reference is : " At Anshan steel works the workers have beaten all British and American productivity records and are well on the way to reaching the Soviet figure." Yet there are reasons to believe that the co-operation has not been altogether very happy. There are now fewer Soviet technicians in China than at any time since the establishment of the Republic, although the volume of construction has not yet reached its pitch.

In some spheres the Chinese seem to have attained tremendous success. A news item from Peking dated September 16th runs as follows : " Workers of the No. 5 Electrical Appliances Factory in Mukden are rushing the completion of China's biggest transformer in honour of National Day, which falls on October 1st. This 13,500kVA transformer will be able to supply enough electric power for a city of 1,000,000 population or four heavy machine factories, each with 10,000 workers." In India the first 2000kVA transformer has yet to be manufactured.



Main Drawing-Office in Parsons Research and Design Building



Office Lighting in Research and Design Building

Lighting a New Research and Design Building

In our issue of July 10th, 1953, page 51, we referred to the lighting system installed in the research and design building at the Heaton Works of C. A. Parsons, Ltd., Newcastle upon Tyne. Further details of this installation have now been received from the General Electric Company, Ltd., who prepared the lighting scheme in collaboration with C. A. Parsons and Co., Ltd., who carried out the architectural design of the building. The scheme was devised to embody cold-cathode tubes in the ceiling construction in such a way that, over most of their area, the ceilings themselves would appear to be the source of light.

This result is achieved, as can be seen from the accompanying illustrations, by rows of reflectors which form the under surface of the ceiling ; as these rows run at right-angles to the normal direction of view from the office desks and drawing boards, the lighting tubes are effectively concealed.

The reflectors are of anodised aluminium, in 9ft lengths, and are perforated to prevent echo, sounds being absorbed by a scrap wool blanket above the fittings. This lighting arrangement also assists the heating system of the building, for the reflectors are clipped to the rectangular hot water pipes in the ceilings and therefore act as radiators of heat. The average heights of the tubes above floor level in the offices are 12ft 6in or 9ft 6in.

Close attention was given to the optical design of the reflectors to avoid a harsh shadow at their longitudinal junctions ; as a result there is nothing to give a definite impression of where the ceiling begins. This absence of a definite indication of its height is effective in preventing an impression of a low ceiling even when looking down the whole length of such a large room as the main drawing-office, which is 216ft long by 60ft wide. Plastic strips are mounted along the joints between reflectors to soften the effect further.

The whole lighting installation in this building incorporates some 7000 " Osram " Intermediate cold-cathode tubes, with a combined length of about 12 miles. Acoustic tiles form the ceiling at the ends of, and between, the panels of continuous lighting, and the transformers are concealed above these sections. Four tubes are operated from each transformer. The maximum width of continuously lighted areas is 27ft (three fittings end to end). In the spaces between these areas the acoustic tiling is interrupted at intervals by laylights with tubes above, to lighten the effect.

Switching is normally automatic under photo-electric control, which first switches on the tubes in the central areas and then those near the windows. Manual control with separate switching of the central block of lights and each outside block throughout each floor is available on the landings through G.E.C. four-pole contactors.

The entrance hall, where there is a portrait of Sir Charles Parsons and showcases containing some historic models made in the course of his early experiments, is lighted by cold-cathode tubes installed above twenty laylights. All corridor lighting is by means of laylights and illumination for staircases is provided by single lines of tubes behind glazed panels on the landings.

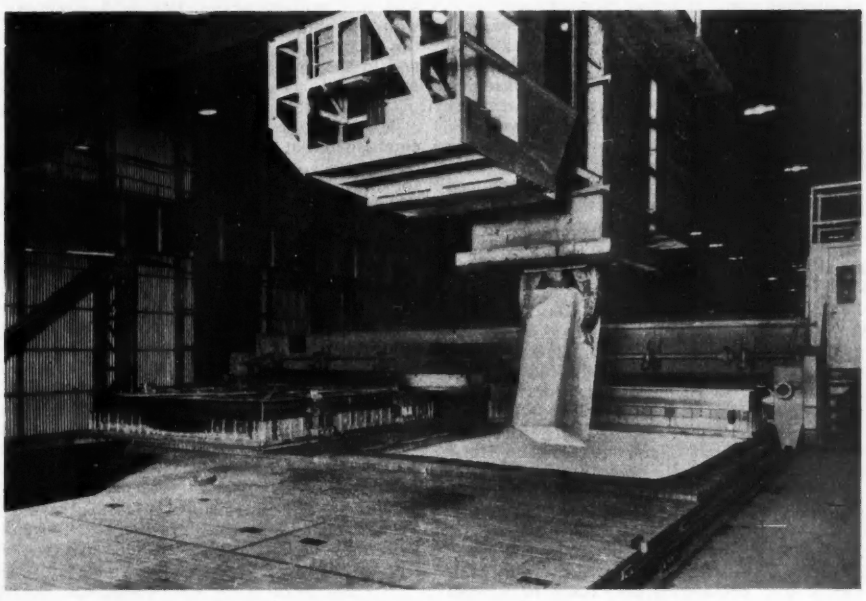
Air Conditioning Equipment for Crane Cabs

A particular problem in the iron and steel industry is the extremely unpleasant working conditions under which employees frequently have to operate in close proximity to where molten and hot metals are being processed. These conditions are due in a large measure to radiant heat, and particular sufferers are crane drivers who cannot readily leave their cabs. A typical instance of this is the case of the driver of the soaking pit crane illustrated on this page. In such a case the temperature in the cab has been known to rise to above 130 deg. Fah., and the direct effects of radiant heat make conditions even worse. Similarly, the cabs of equipment, such as ladle cranes and general service cranes in rolling mills, and operating stations such as the control pulpits in slabbing mills and continuous mills and reheat furnaces often entail equally unpleasant working conditions.

In connection with this problem we have learned from J. and E. Hall, Ltd., of Dartford, Kent, that, by the use of specially designed refrigerating equipment for air conditioning within confined spaces, working conditions have been considerably improved at the Margam works of the Steel Company of Wales, Ltd. This equipment is designed to withstand the mechanical shocks associated with moving structures, and has been arranged to fit the limited space available. One of the refrigeration units is shown in the illustration on page 716.

It has been found that with suitably designed equipment it is possible to maintain automatically a temperature of between 60 deg. and 70 deg. Fah. in a crane cab or a mill control pulpit. These conditions are obtained by the circulation of cool air through a cabin with the constant addition of fresh air and by slightly pressurising the cabin.

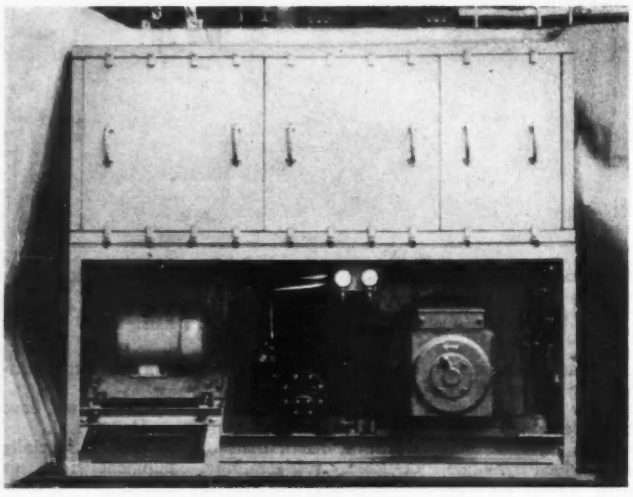
The equipment is made up of standard commercial units and is built into a separate compartment attached to the cabin. It includes a refrigerating compressor, belt driven by a 5 h.p. motor, and a direct expansion air cooler. The air is drawn in through a viscous filter, which removes dust suspended in the atmosphere and an activated charcoal filter which absorbs the sulphurous fumes. The air is circulated through



Soaking Pit Crane

the filters and cooler by a circulating fan and forced through ducting into the cab.

A specially large air-cooled condenser is used, and this is arranged conveniently near to the refrigerating condenser, but in such a position that ample air circulates whilst the unit is protected from radiant heat by means of reflectors. The use of an air-cooled condenser was complicated by the fact that the cooling air available was at a much higher temperature than normal, but this difficulty was successfully overcome. The refrigerant used is "Arcton 6," which was chosen as the most suitable as well as being freely available in this country. Automatic controls are provided to ensure that a temperature of 65 deg. to 70 deg. Fah. is maintained in the driver's cab, and the usual standard safety devices are fitted.



Air-Conditioning Equipment

African Engineering News

(By Our South African Correspondent)

Three Modern Airports for the Union

South Africa will soon have three modern airports—one at Bellville, Cape Town, the Jan Smuts airport near Johannesburg, and the other near Durban. These airports are being built at a cost of about £12,000,000.

The Jan Smuts airport started operating at the end of September, while work on the others is progressing well. It is hoped that the airport at Bellville will be completed by the end of next year or early in 1955, at a cost of about £2,000,000, and that the main runway will be completed by next March. This runway will be 1½ miles long and will be able to carry an aircraft weighing 75 tons. One of the three secondary runways will be completed later next year. The workshops and terminal buildings will be completed soon after the runways. The airport will be equipped with the latest navigational aids. It will replace Cape Town's present air terminal.

Production of Titanium in South Africa

Although the factory now being built at Umgababa, on the Natal south coast, 25 miles from Durban, has for its primary object the manufacture of paints and pigments from ilmenite and also ceramics from zircon, its chief interest so far as engineering developments are concerned lies in its potentialities for the production of titanium from rutile. All these minerals have been found on "Ilmenite Hill," which was discovered in 1951 and the factory, represents a £300,000 project for the purpose of exploiting these minerals. It is estimated that the deposits contain 2,000,000 tons of ilmenite, 200,000 tons of zircon and 100,000 tons of rutile.

The factory is now well on the way to completion and is designed to process 12 tons of zircon, 6 tons of rutile and about 200 tons of ilmenite a day. At this rate the deposits, which are considered to be among the largest in the world, will last for thirty-five years.

Ilmenite Hill is in a most favourable position. The railway line is situated not 100 yards away and the main macadamised South Coast road runs between the beach and the hill front. When completed, the plant will employ about fifteen Europeans and a hundred native workmen. It extends from the hill itself down to the road and two long pipelines are carried under the road and under the railway line to the main section, where several concrete tanks have been built. The concrete-structure for washing the deposits has been built on the beach a few yards from the sea.

Uranium Production

Further important developments in South Africa's uranium production programme have recently been announced. Doornfontein Gold Mining Company, Ltd., has been admitted to the Atomic Energy Board's scheme, and West Driefontein Gold Mining Company, Ltd., is to continue with the erection of a uranium treatment plant, which will treat the uranium-bearing slimes produced at the Doornfontein mine.

The entire capital expenditure involved by this arrangement between the two companies will be financed by loans from British and American sources. The announcement recalls that the erection of the West Driefontein's plant for the extraction of uranium had been deferred in order that plant and equipment could be more economically used elsewhere. Approval has now been received to continue with the erection of the plant which, it is estimated, will be in operation by the middle of 1955. The contract with the Atomic Energy Board of South Africa will be over a period of ten years from the time the plant is in full production.

Twenty-two South African gold mines are now included in the scheme and it is hoped that they will be in full production by the end of 1955.

Electricity Production

More electric power than ever before was sold in South Africa last year by the Electricity Supply Commission, which produced and sold 8080 million units during 1952, compared with 7456 million units during 1951. In spite of this increase the demand on the Witwatersrand and in the Western Cape created by the rapid mining and industrial development exceeded the output and loads had sometimes to be restricted.

The Commission's report says it must be emphasised that there is no short cut to the rapid development of power production on the scale sought in South Africa. During 1952 nearly £20,000,000 was spent on capital account, which increased the total capital expenditure at the end of the year to £88,000,000. The expenditure will amount to £184 million when all the works at present being undertaken, as well as certain projected works, are completed.

Better progress was being made with the erection of new power stations than at any time since the start of the Commission's programme of post-war expansion. This programme involves capital expenditure now estimated at £9,000,000. During 1952 the transmission system was extended from 7413 route miles to 7691 miles. The licensed area of supply is now 104,240 square miles. The aggregate capacity of the Commission's power stations on December 31, 1952, was 1698MW, an increase of 104MW over the corresponding figure for the previous year.

South African Steel Plant

South Africa's new steel plant being erected at Airlie, Eastern Transvaal, for the Dominion Iron and Steel Corporation, Ltd., will probably start its first phase of production by April next year. The furnaces are at present being installed and the last of the heavy machinery is arriving. The rest of the equipment will then be obtained mainly from South African sources.

Conditions indicate that the steel to be produced at Airlie should be amongst the cheapest in the world. The plant is very near the site where the ore is mined and also close to the coal supplies. The company states that the materials required to produce 1 ton of cast iron will cost about £1 5s. at Airlie, compared with £9 or £10 in Britain or the United States.

During the first stage of production about 70,000 tons of pig iron will be manufactured annually. Cast iron products and steel will be manufactured later and the production will be generally expanded. About £1,500,000 has been invested in the project.

The Kafue Hydro-Electric Project

Since the efforts to raise capital for the £30,000,000 Kafue hydro-electric scheme in Northern Rhodesia have been successful, work is to start almost immediately on the project, which has been described as vital to the economy of the newly-formed Central African Federation. It has been stated that, next to federation, this is the most important decision taken in Central Africa for twenty years, and that the completion of the scheme will be a major step in the industrial development of Central Africa.

The scheme was described in THE ENGINEER of February 13th last; it promises an earlier supply of electric power to copper mining areas than from the larger Kariba project, to which it is complementary.

The scheme will take from five to seven years to complete. Two transmission lines, each 240 miles long, will deliver power—totalling 242MW—to the north and south. It is estimated that Kafue's power output will cost 0·258d. per unit. A dam 600ft long and 100ft high will be built across the Kafue Gorge, and two power stations are to be erected, one on the Kafue River and the other on the Keshya River.

Improvement in Union Rail Link with Southern Rhodesia

Good progress is being made to increase the capacity of the Mafeking-Bulawayo railway line and the lines converging at Mafeking. The present Mafeking-Bulawayo section of the South Africa-Rhodesia rail link handled peak traffic last October at an annual rate of nearly 800,000 tons, and it is estimated that the section can be developed to deal with 1,000,000 tons a year. The rail link between South Africa and the Rhodesias has received constant attention from the two Railway Administrations. The volume of traffic worked by South African Railways for the Rhodesian Railways had risen from 161,454 tons in the year ended March 31, 1943, to 701,959 tons during the year ended March 31, 1953.

On the Kimberley-Mafeking section of the line work is proceeding to eliminate the present bottleneck at Beaconsfield. A new "up" yard is being provided at a cost of £185,000. Also 72 miles of track between Fourteen Streams and Vryburg are being rerailed and a section of the line between Kimberley and Fourteen Springs is being deviated and regraded. Additional facilities are being provided at Vryburg, which is an engine changing depot. A scheme is also in hand for the remodelling of the yard at Kamfersdam.

As far as the Union harbours serving the Rhodesias are concerned, No. 2 quay at Port Elizabeth is being double faced, thus making a third quay available, and so increasing the capacity of the port. This and the provision of further cargo sheds will cost more than £1,500,000. An additional three 4-ton and three 15-ton cranes are also being provided. The tanker berths at the port are to be lengthened and deepened to enable larger tankers to be accommodated.

In order to improve the capacity of the Cape Midland main line and to cope more effectively with traffic from Port Elizabeth to the hinterland more than £5,000,000 is being spent on regrading and improving the line. Also nearly £700,000 is being spent on improving and rebuilding wharves in Durban harbour.

Industrial and Labour Notes

Engineering Wages

On Thursday of last week a conference of the executives of the thirty-nine unions comprising the Confederation of Shipbuilding and Engineering Unions was held in London to discuss the rejection of the claim for a 15 per cent wage increase. Prior to the conference, the Confederation's executive council had framed a resolution recommending a twenty-four-hour token strike as a protest against the rejection of the claim.

The resolution as submitted to the conference urged that " at this stage all workers in factories and shipyards should confine their activities to leaving their places of employment for twenty-four hours on a date to be fixed by the Confederation's executive council." After the conference it was stated that the resolution had been passed by a large majority, and that the executive council of the Confederation had decided that December 2nd should be the day for the token strike. The decision of the conference was conveyed, on the following day, to the Minister of Labour by Mr. H. Brotherton, president of the Confederation. In acknowledging the Confederation's letter, the Minister has stated that his department's services are available to the unions and the employers whenever they wish to avail themselves of them.

Wage Demands and Merchant Shipping

In a statement circulated with the annual report of Court Line, Ltd., the chairman, the Hon. J. P. Philipps, comments on the " considerable deterioration in the level of freight rates." He says that it accentuates the feeling of concern at the latest demands for increased wages not only for the Merchant Navy, but for the shipbuilding and engineering industry. The statement goes on to comment that, despite the unrealistic contentions of the unions, these demands, if met, can only have the effect of increasing still further the cost of new tonnage to shipowners and so reducing their resources for replacement of old tonnage.

It is also perfectly obvious, Mr. Philipps continues, that the higher the initial cost of the vessel the greater must be the annual provision for depreciation, which can only be provided out of earnings. It is essential, therefore, the statement adds, that those in control of the shipbuilding and engineering unions should face up to the facts and help their employers to reduce costs instead of regularly increasing them. Otherwise, Mr. Philipps says, few new orders will be placed with British shipyards, a trend which can already be seen from the recent shipbuilding returns.

Overseas Trade

In its trade and navigation accounts for October, the Board of Trade gives the final figure of £227,600,000 as the value of exports of United Kingdom goods. Imports in October were valued at £279,800,000, and re-exports at £9,300,000, so that the excess of imports (valued c.i.f.) over total exports (valued f.o.b.) was £42,900,000.

The Board says that exports in October were higher than in any month previously this year, except July, but that the increase, compared with the third quarter's average, was largely accounted for by the fact that October was not affected by industrial holidays, and that it had one more working day than the average of the preceding three months. It is stated that these and other seasonal factors have usually resulted in recent years in a high export total in October. This year, the October increase has continued the very slow upward trend in exports which has been evident since the first quarter. The July to October average was 3 per cent up on the first half of the year, and the export total for the first ten months was only 2 per cent less than the amount for the corresponding period of last year, in spite of the exceptionally high rate of exports to certain sterling markets in the early months of that year.

But the Board of Trade has pointed out that the slight improvement in the export total in recent months owes much to increases in shipments of textiles and the category covered by " other manufactures." Although exports of engineering products recovered in October to £84,000,000, which was £3,000,000 more than the low rate in the third quarter, they were still below the average for the first half of the year. As a result of the low figures recorded for engineering products in the third quarter, the monthly average from July to October was £82,000,000, or £5,000,000 less than the average for the comparable period of 1952, most of the decrease being accounted for by machinery and vehicles. These two groups, however, contributed most of the increase in the month of October, compared with the third quarter, but whereas exports of vehicles in the month were nearly £1,000,000 above the monthly rate from January to June, exports of machinery remained at about £1,000,000 below that rate.

It has been estimated that United Kingdom exports to the sterling area in October have been estimated provisionally to be nearly 9 per cent more than in the third quarter, when the figure was already higher than in any quarter since the exceptionally high total in the first quarter of 1952. The October total remained substantially below that record. Exports to the non-sterling area are also estimated to have been over 6 per cent higher than in the third quarter.

National Production Advisory Council

Last Friday, the National Production Advisory Council on Industry held a meeting in London, under the chairmanship of the Chancellor of the Exchequer, Mr. R. A. Butler. The council includes representatives of the Federation of British Industries, the British Employers' Confederation, the National Union of Manufacturers, the Association of British Chambers of Commerce, the Trades Union Congress, the nationalised industries, and the Regional Boards for Industry. Its terms of reference are " to advise Ministers upon industrial conditions and general production questions and on such subjects as may arise from the proceedings of the Regional Boards for Industry."

Last week's meeting began with an introductory statement by the Chancellor of the Exchequer, in the course of which he said that the improvement in exports since the first quarter of this year had been very slow. The " stickiness " of exports, with the volume of imports higher than in the preceding year, suggested that any complacency about the current surplus would be out of place. The Chancellor went on to say that United Kingdom exporters tended to be slower than their competitors in adjusting prices to changes in world markets. In many important non-sterling markets we appeared to have been losing ground to our competitors pretty steadily over the last two years. The U.S.A. in particular was able to cut prices to meet growing competition and to clear stocks. An expansion of our exports, therefore, required more than the ability to meet competitors on price, quality and delivery. It was necessary, the Chancellor emphasised, to be competitive in selling.

Industrial output, the Chancellor continued, was high ; in the first three-quarters of this year it had been 5 per cent above 1952 and 1 per cent or so higher than in 1951. But, he explained, much of the increase had come from the building industry, and manufacturing output alone was barely back to 1951. Coal output was not satisfactory, and there had been a slight fall in engineering output. Engineering, the Chancellor observed, had a key part to play in increasing the country's total volume of exports, but in the first three-quarters of the year the volume of engineering exports was lower than last year. Furthermore, the Chancellor said, most of this year's rise in production had derived from an increase in home demand and not from higher exports. Some rise in consumption was probably a necessary condition of higher investment, and fuller use had been made of resources otherwise idle. But a continuance of rising imports, unaccompanied by rising exports, would threaten the balance of payments.

Concluding his statement, the Chancellor said that productivity had probably recovered to the 1951 level, which was gratifying. Given the investment in plant and machinery since 1951, however, we could not be satisfied with the pace at which new industrial knowledge was spreading until the curve of productivity was rising strongly. To get the increase in exports, this country must more than match the growing efficiency, productivity and competitive power of other industrial nations.

Europe's Coal Position

The Organisation for European Economic Co-operation has issued a report which has been made by its coal committee on the coal position in Europe in 1953 and 1954. The first part of this report analyses coal production figures, both as a whole and in each of the main European producing countries, which have been estimated from present output rates. Consideration is then given to consumption trends in the main sectors of each country.

In February last the coal committee estimated that coal output for this year could be raised to 487,200,000 tons, but new estimates which have been submitted by the various countries show that the figure is not likely to exceed 476,600,000 tons, or 1,500,000 tons more than in 1952. Next year's production is estimated at 488,300,000 tons. The report shows that consumption this year is likely to be about 489,500,000 tons, and 498,500,000 tons in 1954. In these circumstances, it is stated, Europe's apparent coal deficit, which was running at 27,400,000 tons in 1952, will probably be reduced to between 12,000,000 and 13,000,000 tons this year, and in 1954 could probably be covered entirely or partially by drawing on pithead stocks if qualities are suitable. The report goes on to say that these figures should be interpreted with great caution owing to uncertainty as to the future trend of economic activity. They suggest, however, that if allowances are made for some withdrawals from stocks held by consumers, and a constant tonnage of coal imports from Eastern Europe, the deficit which would still have to be covered by imports of American coal might certainly not exceed 5,000,000 or 6,000,000 tons this year and might even drop to a lower figure in 1954. Last year 20,300,000 tons of American coal were imported by Europe.

One observation made in the report is that increased output in the two main coal producing countries—the United Kingdom and Western Germany—was arrested this year by the extension of holidays in the first and the shortening of the working day in the other. Everything must be done, the report says, to find ways and means of restoring the loss of output, particularly as Germany is the main producer of coking coal, the shortage of which is likely to continue in 1954.

Simplifying Foundry Operation

This week the Council of Ironfoundry Associations and the British Cast Iron Research Association are holding a conference at Ashorne Hill, Leamington Spa, on simplifying foundry operation. It opened on Wednesday and will conclude to-day (Friday). The papers which are being presented have been designed to show how economies in human effort, and reduction in production costs, can be achieved through the commonsense analysis of ironfoundry operations. Particular emphasis is being given to the problems of smaller firms. Another point which is being stressed at the conference is that the ability to look at familiar jobs in the foundry from a new angle can lead to practical improvements, often without requiring expenditure on equipment.

Notes and Memoranda

Air and Water

LAUNCH OF ADMIRALTY TUG.—The Admiralty tug, "Superman," which has a length of 180ft by 37ft beam, was launched in November 23rd at the Aberdeen yard of Alexander Hall and Co., Ltd.

LAUNCH OF LIGHT VESSEL.—Light vessel No. 15, which is under construction for the Corporation of Trinity House at the Noss works of Philip and Son, Ltd., was launched on November 18th.

MACHINERY RESEARCH.—We are informed by Yarrow and Co., Ltd., that the company's research department, which was formed some time ago to evolve advanced designs of naval machinery in co-operation with the Admiralty, is engaged in investigating the use of higher steam pressures and temperatures for class of machinery.

DIVING BOAT.—A diving boat measuring 40ft in length by 10ft 6in beam by 4ft 6in deep has been delivered by Brooke Marine, Ltd., to the Manchester Ship Canal Company for work on the company's canals. The boat is built of steel and is powered by a Gardner Mk.2.LW engine of 24 b.h.p., driving through a 2 to 1 reduction gear.

AUSTRALIAN "FIREFLY" TRAINER.—A new two-seat trainer version of the Fairey "Firefly" multi-purpose naval aircraft the T.Mk. 5, has been developed by the Fairey Aviation Company of Australasia Pty., Ltd., Bankstown, New South Wales. It is the first aircraft engineered by this branch of the Fairey Group and marks one more stage in the steady growth of its subsidiaries from repair and maintenance bases to design and production units.

LAUNCH FOR PAKISTAN.—The Pakistan Industrial Development Corporation has taken delivery of an aluminium alloy launch 26ft in length by 7ft 4in beam and having a draught of 1ft 10in. Welding by the "Aircomatic" process has been extensively used in the construction of the launch which was built by Brooke Marine, Ltd., and is powered by a Perkins P.6.M. diesel engine developing 65 b.h.p. at 2000 r.p.m., and driving a three-bladed cast aluminium alloy propeller.

OIL FIRES AT SEA.—A new method of fighting oil fires at sea was demonstrated recently before officials of Lloyd's Register of Shipping and shipowners, the method employed being a water-fog produced by a Megator pump. In one test an oil fire simulating its counterpart in an engine-room was extinguished in thirty seconds with the use of 50 gallons of water in the form of water-fog through eight "Fognozls," while in another test a blazing oil tank was extinguished in about twenty seconds by the application of water-fog through "Fognozls," 15 gallons of water being used.

Miscellanea

INSTITUTION OF MINING ENGINEERS.—The Council of the Institution of Mining Engineers states that H.R.H. The Duke of Edinburgh has graciously consented to accept Honorary Membership of the Institution.

MR. D. M. BROWN.—We have learned with regret of the death, on November 17th, of Mr. Donald M. Brown, director and commercial manager of Keith Blackman, Ltd., Tottenham, N.17. Mr. Brown, who was in his seventieth year, had been in the company's service for fifty-four years.

WORLD TIN OUTPUT.—Advance estimates given by the International Tin Study Group show that output of tin is increasing in all important production centres. During September the world mine production of tin totalled 14,800 tons, as compared with 13,600 tons in August.

COAL PRODUCTION.—It is announced that last week the production of deep-mined coal was the highest for the past thirty weeks and it amounted to 4,480,300 tons. During the first forty-six weeks of this year coal output totalled 197,533,600 tons, as compared with 199,929,800 tons for the same period last year.

NEW COALFIELD IN MIDLANDS.—It is estimated that the new coalfield, which was discovered in 1949 in South Staffordshire, contains at least 400 million tons of coal, and it is thought that it links the Cannock and Warwickshire coalfields. The coal, discovered at about 3000ft, is in seams from 5ft to 8ft thick, it is believed.

BRITISH COMPRESSED AIR SOCIETY.—The British Compressed Air Society has just published a new booklet which describes in detail the aims, objects and activities of the Society and the benefits of membership. Copies of the booklet are obtainable from the secretaries of the Society, Peat, Marwick, Mitchell and Co., Ltd., 94/98, Petty France, London, S.W.1.

SELLING PRICES FOR TUNGSTEN ORES.—The Ministry of Materials has stated that, as from November 24th, its selling price for tungsten ores of standard 65 per cent grade and ordinary quality has been reduced as follows:—Wolframite from £11 5s. to £10 10s., and scheelite from £10 10s. to £9 15s. per long ton unit, delivered consumers' works.

COAL STOCKS.—The Minister of Fuel and Power, Mr. Geoffrey Lloyd, stated, in reply to a question in Parliament last Monday, that distributed coal stocks on November 14th amounted to 19,000,000 tons, compared with 19,400,000 tons a year ago, and 17,100,000 tons on the corresponding date in 1951. House coal stocks, the Minister said, were at about the same level as last year and there were still some 200,000 tons of imports due to arrive before the end of the year.

MINISTRY OF SUPPLY CONTRACTS.—In a written Parliamentary reply, Mr. Duncan Sandys states that, during the last financial year, the Ministry of Supply placed approximately 250,000 contracts to the value of about £630 million. These contracts were spread among some 10,000 firms. The reply says that the figures include contracts placed both by the Ministry's headquarters and its out stations, but they do not include orders placed by the Ministry's headquarters with the Royal Ordnance Factories and Agency Factories.

CAREERS IN CHEMICAL ENGINEERING.—About 180 boys and careers and science masters from grammar and public schools in the London area attended a meeting arranged by the Institution of Chemical Engineers on November 18th to hear something of the profession of chemical engineering. Professor M. B. Donald, Ramsay Professor of Chemical Engineering at the University of London and chairman of the Institution's education committee, spoke on the profession and the opportunities which it offered. Mr. E. Le Q. Herbert, of the Shell Refining and Marketing Company, Ltd., then introduced the film "The Stanlow Story," which shows the building of one of Britain's new oil refineries involving a great deal of chemical engineering. After the film Professor Donald and Mr. F. E. Warner answered questions put on the subject of chemical engineering as a profession.

AN AUTOMATIC SWITCH POINT FOR MINE CARS.—A self-acting switch point which automatically separates full and empty coal tubs has been designed by Mr. G. G. Carr, enginewright at Trimdon Grange Colliery, Durham. The inner rail of the switch point is balanced so that when a full tub runs on to it and passes over the fulcrum it is tipped downwards by the tub's weight. The tipping of the rail operates a lever unit which swings the points into position to take the tub on to the full road. After the tub has passed over the points the whole sequence is reversed by a counterweight on the layer unit and the points return to their original position. The counterbalance is so arranged that the weight of an empty tub is not sufficient to operate the mechanism. To ensure that full tubs pass over the points singly, the butt end of the balance rail acts as a check and returns to the level position when the points are clear.

F.B.I. OVERSEAS SCHOLARSHIPS SCHEME.—The Federation of British Industries has announced that Dr. W. Abbott, C.M.G., formerly H.M. Staff Inspector of Engineering at the Ministry of Education, has been appointed Director of Studies in connection with its overseas scholarships scheme. Mr. W. V. Jenkins, who has been responsible for the operation of the scheme since its inception, remains manager. The first two groups of scholars from Latin America have now arrived and have begun their training at engineering works in this country. Four are from Peru and three from Cuba. Scholars from other Latin American Republics are expected shortly. Three more Indian scholars have also begun their training, giving a total of twenty-six graduates who are receiving their training under the F.B.I. scheme. Six have already returned home after completing their training. The scholarship scheme now includes Australia, India, Pakistan, Chile, Cuba, Peru, Iran and Sudan, and is in process of being extended to other British territories and certain foreign countries, especially in the Middle East.

INSTITUTE OF METALS ESSAY COMPETITION.—The Institute of Metals states that entries for its students' essay competition must reach the secretary at 4, Grosvenor Gardens, London, S.W.1, on or before January 1, 1954. Two prizes of twenty guineas each may be awarded for the best essays submitted in accordance with the regulations. Each prize will be in the form of ten guineas in money and ten guineas in scientific, technical or other appropriate types of books, to be selected by the prizewinner. The competition is open to student members of the Institute, and to all associate members of local sections who are eligible for student membership of the Institute, provided that both are within the age limits of seventeen to twenty-five years. The competition is not restricted to persons who are undergoing courses at a university or technical college; it is open to all persons within the age limit stated. Essays must be submitted in English; they should be 2500–3500 words long and must not exceed 3500 words. They must be submitted in typewritten form with double-line spacing. The choice of subject is left to the competitors, except that subjects relating exclusively to extraction or ferrous metallurgy are ineligible. It is intended, though this may be varied as may be found necessary, that one prize shall be awarded for a paper on a theoretical subject and the other for a paper on a practical subject. The subject matter should be logically presented, in good English, and should have a metallurgical content to impress the adjudicators by soundness, exercise of critical faculty and originality of approach. Entries must be accompanied by a certificate, signed by the entrant, that the essay itself is entirely his or her own work; that it has not, in the form in which it has been sent, been submitted for any other competition, and clearly stating what (if any) drawings, photographs, &c., have been prepared on his or her behalf.

Contracts

STEWARTS AND LLOYDS, Ltd., has received through Williams Brothers, the American contractors, an order for several hundred miles of line pipe for the Haines-Fairbanks pipe project in British Columbia and Alaska. The value of the order is approximately £1,000,000 and will be paid for in dollars. It is stated that the manufacture of the pipe will be undertaken in the company's works at Glasgow, South Wales and the Midlands.

Personal and Business

W. J. FRASER AND CO., Ltd., states that, as from December 1st, its address will be Harold Hill, Essex.

MR. B. J. BRADFORD has been appointed publicity manager of The Rheostatic Company, Ltd., Slough, Bucks.

THE PROJECTILE AND ENGINEERING COMPANY, Ltd., states that Mr. E. L. Tuff, works manager, has been appointed a director.

MR. E. F. WARD has been appointed assistant manager in the contracts department of Johnson and Phillips, Ltd., Charlton, London, S.E.7.

MR. R. W. ALLEN has been appointed North-East area representative for Nife Batteries, Redditch, in succession to Mr. S. K. Hodgkinson.

E. G. BROWN AND CO., Ltd., West Road, Tottenham, N.17, states that Mr. F. Wale has been appointed managing director in succession to the late Mr. E. G. Brown.

MR. F. A. A. MENZLER, chief development and research officer, London Transport Executive, has been appointed a member of the Royal Commission on the Civil Service.

THE TELEGRAPH CONSTRUCTION AND MAINTENANCE COMPANY, Ltd., Greenwich, S.E.10, announces the appointment of Mr. Ralph Fenwick as technical sales representative for the North-Eastern area.

THE NATIONAL COAL BOARD announces the following appointments: Dr. J. Smillie, production director of the West Midland division, and Mr. J. M. Pumphrey, production director of the Northern division.

VICKERS-ARMSTRONGS, Ltd., states that Mr. J. R. Kelly is joining the board on December 1st and will take over the office of general manager of the Crayford and Dartford works and the Whitehead torpedo works.

SMITH'S INDUSTRIAL INSTRUMENTS, Ltd., announces the appointment of Mr. M. D. Davidson as Scottish technical sales representative operating from 153–155, Bothwell Street, Glasgow, C.2 (telephone, Glasgow Central 3972).

MAVOR AND COULSON, Ltd., has announced the retirement of Mr. John C. Smith, district manager for mining machinery in Northumberland and Durham, after thirty-two years' service. His successor is Mr. J. H. Rogan, 1, Eldon Square, Newcastle upon Tyne, 1.

Launches and Trial Trips

HENRI POINCARE, passenger liner; built by the Chantier et Ateliers de Saint Nazaire Penhoet for the Compagnie Maritime des Chargeurs Réunis; length between perpendiculars 502ft, breadth moulded 64ft 4in, depth to upper deck 41ft, draught 27ft 11in, load displacement 17,500 tons, deadweight 9000 tons, designed speed 17 knots, three complete decks nine watertight compartments; ninety-one first and fifty-two second-class passengers, and 398 steerage; two Sulzer single-acting, two-stroke diesel engines, eight cylinders, 720mm diameter by 1250mm stroke, total of 10,000 h.p. at 120 r.p.m.; 12,000 h.p. at 130 r.p.m.

ELPENOR, passenger and cargo liner; built by Harland and Wolff, Ltd., for Alfred Holt and Co.; length between perpendiculars 452ft 9in, breadth moulded 62ft, depth moulded 35ft, gross tonnage 8300, four main cargo holds; Harland-B. and W. two-cycle, opposed-piston oil engine, seven cylinders, 750mm diameter by 2000mm combined stroke, 107 r.p.m., three 220kW diesel-driven generators, one vertical multi-tubular boiler. Launch, November 11th.

CASTOR, minesweeper; built by Les Chantiers et Ateliers Augustin Normand, for the French Navy; length overall 46·30m, breadth moulded 8·50m, mean draught 2·28m, displacement 424 tons; two sets of free-piston compressors and double-reduction geared gas turbines, 1800 s.h.p., speed 15 knots. Launch, November 19th.

BORDER KEEP, oil tanker; built by the Blythswood Shipbuilding Company, Ltd., for the Lowland Tanker Company, Ltd.; length between perpendiculars 515ft, breadth 69ft 6in, depth moulded 37ft 6in, deadweight 16,150 tons, twenty-seven cargo oil tanks, two pump rooms, four 500 tons per hour cargo oil pumps; Rowan-Doxford two-stroke, opposed-piston oil engine, six cylinders, 670mm diameter by 2320mm combined stroke, 6800 b.h.p., two Scotch boilers, speed 15·5 knots. Trial, November 19th.

SIR DAVID II, self-trimming collier; built by Hall Russell and Co., Ltd., for the North Thames Gas Board; length between perpendiculars 320ft, breadth moulded 46ft, depth moulded to raised quarter deck 27ft 10in, four holds; one direct-acting, triple-expansion "North-Eastern Reheat" steam engine, 1275 i.h.p., superheated steam supplied at 220 lb per square inch by two cylindrical boilers. Launch, November 20th.

JARENA, oil tanker; built by Harland and Wolff, Ltd., at Belfast, for Anders Jahre and Co., Norway; length between perpendiculars 540ft, breadth moulded 73ft, depth moulded 39ft 3in, deadweight 18,500 tons, twenty-seven cargo oil tanks, two pump rooms; Harland, and Wolff-B. and W. single-acting, two-cycle, opposed-piston oil engine, six cylinders, 750mm diameter by 2000mm combined stroke, 114 r.p.m., two cylindrical multi-tubular boilers, two 75kW steam-driven generators, one 75kW diesel-driven generator. Trial, November 20th.

British Patent Specifications

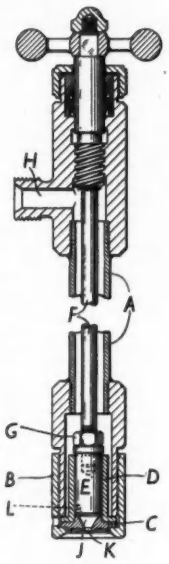
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application: the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

BURNERS AND SPRAYERS

699,162. November 30, 1951.—Liquid Fuel Burner of the Vortex Chamber Type, Shell Refining and Marketing Company, Ltd., St. Helen's Court, Great St. Helen's, London, E.C.3. (*Inventor: John Ruskin Joyce.*)

The object of the invention is to provide a burner in which the reduction of spray cone angle with increasing fuel flow is diminished. The burner shown in the drawing comprises a hollow casing *A*, of which the forward end is threaded to receive a cap *B* to hold in position an orifice plate *C* and a flanged swirl sleeve *D*. The sleeve has a cylindrical bore in which fits a control piston *E* which is screwed on the lower end of a rod *F* and is secured by a lock-nut *G*. The upper end of the rod is threaded in the burner casing, so that by turning the control handle the piston *E* can be moved axially in the sleeve *D*. Fuel is admitted under pressure through a union connection *H* to the interior of the casing. Formed partly in the orifice plate *C* and partly in the sleeve *D* is a vortex chamber *J* having an outlet *K*. The chamber is bounded at its rear by the front face of the piston *E*. Identical slots *L* are provided in each of the three faces of the swirl sleeve, and these slots constitute the inlet ports through which fuel can flow from the interior of the casing into the vortex chamber. The control piston is shown in its minimum fuel flow position. In this position it cuts off the whole of each port *L* except a small portion at the forward extremity and allows the minimum flow of fuel required in operation of the burner to enter the vortex chamber. If the piston is withdrawn, successively increasing portions, and finally the whole, of the slots *L* are opened, allowing the flow of fuel to increase to its maximum.—*October* 28, 1953.

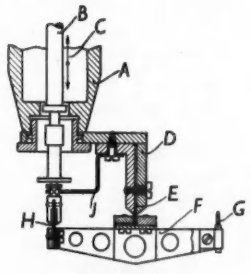


No. 699,162

INSTRUMENTS AND MEASURING DEVICES

699,217. November 28, 1951.—Indicating or Recording the Roughnesses or Undulations of Surfaces, Ernst Leitz, G.m.b.H., Wetzlar, Germany.

The device shown in the drawing comprises a fixed head *A* in which a spindle *B* is guided and leads to an indicating or recording device which may be a mirror or an electric arrangement. The spindle *B* is caused to perform oscillations generated by an extraneous oscillator so that it oscillates in the direction of the double arrow *C*. Fixed to the head is a bracket *D* in which a weak flat spring *E* is provided. The spring forms the fulcrum of a double-armed lever *F* carried by the spring. At one end of the lever a sensing needle *G* is fixed, the other end of the lever being connected by a further flat spring *H* to the spindle *B*. A holder *J* secures the spindle in position. Preferably, the two springs are so weak that the characteristic frequency of the lever lies below the frequency of the oscillations impressed on the spindle. In use, oscillations are transmitted over the spindle *B*, the spring *H*, the lever *F* to the sensing needle *G*, which passes along a surface under test. Irregularities in the surface are sensed by the sensing needle, which correspondingly reciprocates, the reciprocations being superimposed on the oscillations and being transmitted over the lever *F*, the spring *H*, the spindle *B* to an indicating or recording device.—*November* 4, 1953.



No. 699,217

FURNACES

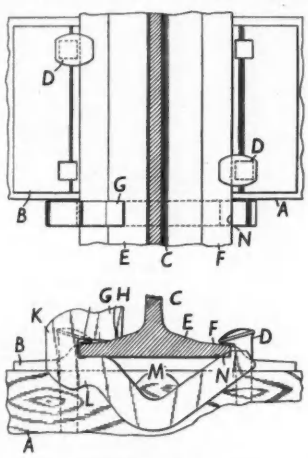
699,251. November 29, 1950.—Sheet Metal Combustion Chambers and Flame Tubes, Joseph Lucas, Ltd., Great King Street, Birmingham, 19. (*Inventor: William Bonsall.*)

The invention relates to an air-jacketed sheet metal combustion chamber, flame tube, or other like tubular body of the kind used in a jet engine, or gas turbine, in which hot gases are generated or conveyed, the surface of the body having holes for the admission of air from the jacket. One of the difficulties experienced is the cracking of the edges of the holes due to stresses set up in the metal by the heating action of the gases. The invention consists in forming in the metal around the holes, transverse corrugations to allow free expansion and contraction of the metal at the edges of the holes.—*November* 4, 1953.

RAILWAY ENGINEERING

697,571. October 3, 1951.—Rail Anchors, The P. and M. Company (England), Ltd., 1A, Grosvenor Gardens, London, S.W.1.

The drawing shows a sleeper *A* having a chair *B* supporting a rail *C* and held by spikes *D*. The rail is of the type in which the top face portions of the flanges E have a greater inclination from the horizontal than the portions *F* at the outer edges of the flanges. The invention is, however, not limited exclusively to this type of rail. The anchor is formed from a heavy bar of steel 1in in cross section, and it comprises a jaw *G* which engages the top face of the flange in mid-position. An inclined flat *H* is formed along the lower corner of the hook, to abut the face of the flange. It will be seen that there is a substantial clearance between the top surface of the jaw and the rail base. A vertical bar portion of the anchor K engages the end face of the flange, while a horizontal bar portion *L* provides a bearing for the bottom edge face of the flange. A wide V-portion forms a supplementary part of the anchor body, the apex being curved with straight leg portions *M*. The juncture of the two legs provides a bearing on the vertical face of the sleeper at a substantial distance below the rail. The outer leg is provided with a rectangular notch, one side of which forms the shoulder *N* which engages the edge face of the rail base and prevents the anchor from moving in a transverse direction. The design of the V section allows the anchor bar to adapt itself readily to grip on the rail, and reduce the strain on the hook-shaped end. The specification also describes in detail the production and fitting of the anchor, and shows several modified designs.—*September* 23, 1953.



No. 697,571

METALLURGY

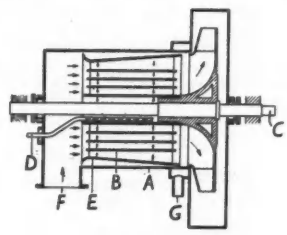
699,209. September 12, 1951.—Producing Structural Steel of High Yield Strength, The Vereinigte Oesterreichische Eisen- und Stahlwerke Aktiengesellschaft, Muldenstrasse 5, Linz a. Donau, Upper Austria.

The specification describes a process for the preparation of unalloyed or low-alloyed carbon steels with increased yield strength, characterised in that the steel is melted in a basic open-hearth furnace in the ordinary manner or in a basic open-hearth furnace or basic converter by blowing with a high oxygen blast, a final slag having a ferrous oxide content exceeding 20 per cent being obtained, and the melt receives an addition of more than 0·5kg per ton aluminium or more than 0·2kg per ton titanium, or more than 0·2kg per ton magnesium, or more than 0·2kg per ton of a mixture of the latter two constituents. The process is characterised in that steels blown in the usual manner are placed after the final blow in a separate container in contact with a slag having a ferrous oxide content in excess of 20 per cent and then the additions specified are made.—*November* 4, 1953.

FILTERS AND SIEVES

699,338. May 5, 1952.—Washer for Air or Gas Containing Dust, Zschocke-Werke Aktien-Gesellschaft, Kaiserslautern (Pfalz), Germany.

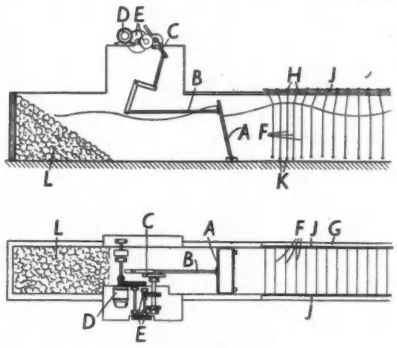
As shown in the drawing, the gas is led through a washer casing *A* in which rotates a drum rotor The rotor is composed of several perforated sheet metal open-ended cylinders *B*, called spraying drums, which are arranged concentrically one within another. Between the shaft *C* and the innermost spraying drum washing water is delivered through a pipe *D*. The water passes through the slots of the rotating drum and is finely atomised as a result of the centrifugal force and flung against the inside of the second spraying drum. The water then passes through the slots of the second spraying drum and is flung against the inside of the third spraying drum. This is repeated until the washing liquid has passed through the last drum. The washing liquid is collected and led out of the washer by a collecting drum *E*. The washing liquid forms over the whole cross section of the washer a dense spray which is directed transversely of the gas current. The distance between any two cylinders is made only of such a size that the very fine water particles strike with great velocity on the next spraying drum before they are caught by the gas current and substantially deviated out of their radial direction. The washing liquid increases its dust content on its path through the current of gas which has entered through the pipe *F*, the liquid leaving the washer by way of the outlet pipe *G*.—*November* 4, 1953.



No. 699,338

699,418. January 2, 1951.—Apparatus for Generating Waves, Jean Abel Larras, 14, Boulevard Baudin, Alger (Algeria), and Jean Laurent, 10, rue Eugène Renault, Maisons-Alfort (Seine), France.

The invention relates to apparatus for generating waves in a body of liquid. The apparatus comprises a rigid shutter *A* pivoted for oscillatory movement about its lower edge and oscillated to and fro by a connecting-rod *B* controlled, through an appropriate linkage, by an eccentric *C* actuated from a motor *D* through reducing gears *E*. The regulation of the period of the generated waves is effected by modifying the speed of the motor *D* and the regulation of the wave camber is effected by varying the effective throw of a crankpin carried by the eccentric *C*. The apparatus includes also a number of flexible curtains of jute canvas *F* placed successively downstream from the shutter *A* in a channel *G*. Each curtain is supported by a cross-bar *H* supported in notches formed on longitudinal bars *J* on both sides of the channel. The lower end of each curtain is loaded with a rigid cross-bar *K*. Both the spacing and the number of curtains to be employed affect the characteristics of the waves to be generated, and they can be adjustable at will. An inclined heap of pebbles *L* at the end of the channel forms a damping arrange-



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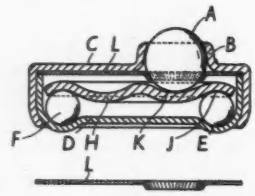
ment. Experiments have proved that the generating assembly thus constituted has the double advantage of producing clear waves and preventing the eventual return waves from being reflected on to the apparatus. —*November* 4, 1953.

BEARINGS AND SUPPORTS

699,010. June 26, 1952.—LOAD BALL BEARINGS, Autoset (Production), Ltd., 72, Stour Street, Birmingham, 18 ; and Claude Mortimer Townsend, of the company's address.

The invention relates to an anti-frictional bearing device in which a load contact ball is located to revolve within, and project from, an eccentrically disposed locating sleeve provided in a cap. As will be seen from the drawing, the load ball *A* is located within an outer sleeve *B* arranged eccentrically upon a circular closing cap *C*. This cap has sides closed around a cup *D* formed with a boundary ball-race *E* between the sides and a raised middle part constituting the bottom of the cup. The closing serves to rigidly



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connect the cap and the cup. Within the cup *D*, freely turning on a ring of balls *F* is a table *H* disposed concentrically to the cap and cup, the under surface of this table being provided with a counterpart ball-race *J* to the race *E* and the upper surface being provided with an inner race *K* for the load ball. This arrangement allows the ball to revolve the table *H* relative to the ring of balls *F* on the ball-race *E*. Against the underside of the cap *C* is secured a disc form of washer *L* having a hole engaging the lower portion of the load ball. This hole has a flange providing the resilient pressure by closely split spring tongues. The load ball *A* is lightly floated between the sleeve *B* and the table *G* by reason of the washer *L*, whereby when the ball is unloaded its upper surface seals the outer opening of the sleeve and when it is loaded sealing is provided by the resilient contact of the washer with the under surface. The design is specially suitable for working in dusty situations—*October* 28, 1953.

TOOLS AND WORKSHOP APPLIANCES

698,910. June 20, 1951.—CUTTING TOOLS, The Birmingham Small Arms Company, Ltd., Armoury Road, Small Heath, Birmingham. (*Inventors : Donald Arthur Oliver and Kenneth Jack Blackler Wolfe.*)

According to the invention, tools, such as drills, milling cutters, lathe tools and reamers, made from a ferrous alloy containing at least 4 per cent of either molybdenum or boron, are treated to convert either the molybdenum or the boron in the surface of the tool to either molybdenum disulphide or boron nitride. Preferably the alloy contains about 9 per cent of molybdenum or boron. A cutting tool made from such an alloy may be treated with any suitable sulphurising or nitrogenising method to provide the surface layer of either molybdenum disulphide or boron nitride. For the former, use may be made of a solution of an alkaline polysulphide, for example, sodium polysulphide, and for the latter any of the known suitable processes for the nitriding of steel may be employed. Care must be taken in the case of molybdenum disulphide to avoid the presence to an undesirable extent of molybdenum trisulphide (MoS_3).—*October* 28, 1953.

Catalogues

NEWMAN INDUSTRIES, Ltd., Yate, Bristol.—Catalogue of flameproof motors.

THE RADIOCHEMICAL CENTRE, Amersham, Buckinghamshire.—Catalogue of radio-active materials.

BRITISH JEFFREY-DIAMOND, Ltd., Wakefield, Yorks.—Catalogue No. 1488, "Swing Hammer Shredders."

B.E.N. PATENTS, Ltd., High Wycombe, Bucks.—Literature describing the new type "W.H." spray gun; leaflet CB 108, "Farm Maintenance," giving details of portable and stationary air compressors recommended for general use on farms and estates.

B.I.P. TOOLS, Ltd., Tyburn Road, Erdington, Birmingham, 24.—Booklet entitled "Moulds and Mouldings."

G. AND J. WEIR, Ltd., Cathcart, Glasgow.—Publication No. 37/2, "Eliminate Corrosion in the Power Plant."

JAMES NEILL AND CO. (SHEFFIELD), Ltd., Napier Street, Sheffield, 11.—Leaflets dealing with box and swivel angle plates.

FOSTER TRANSFORMERS, Ltd., South Wimbledon, London, S.W.19.—Leaflet describing voltage regulating equipment.

THE LEAD WOOL COMPANY, Ltd., Snodland, Kent.—Leaflet describing new portable air compressor, type "ACD 210."

GEORGE W. KING, Ltd., Hitchin and Stevenage, Hertfordshire.—Catalogue illustrating the crane services of Geo. W. King.

J. E. BATY AND CO., Ltd., 39, Victoria Street, London, S.W.1.—Latest edition of the "Baty" measuring instrument catalogue.

UNITED EBONITE AND LORIVALE, Ltd., Little Lever, Near Bolton, Lancs.—Booklet describing the "Lorivale Plastics Plan."

POLLARD BEARINGS, Ltd., Ferrybridge, Knottingley, Yorkshire.—Catalogue describing the latest range of "Max-Load" bearings.

THE RHEOSTATIC COMPANY, Ltd., Slough.—List No. 121, describing "Satchwell" motorised valves for high-pressure hot water.

VISCO ENGINEERING COMPANY, Ltd., Stafford Road, Croydon.—Booklet No. 532, describing modern dust-collecting and fume removal.

ROBERT KELLY AND SONS, Ltd., 55, Market Street, Manchester, 1.—Leaflet describing the "D.F.S." shrinking and stretching machine.

JAMES GORDON AND CO., Ltd., Dalston Gardens, Stanmore, Middlesex.—Catalogue H.41, "Pressure Reduction and Desuperheating."

TELEFLEX PRODUCTS, Ltd., Teleflex Works, Chadwell Heath, Essex.—Catalogue of Teleflex industrial remote control equipment.

CAMBRIDGE INSTRUMENT COMPANY, Ltd., 13, Grosvenor Place, London, S.W.1.—Leaflet sheet No. 311, "Cambridge Recording Controller."

MONSANTO CHEMICALS, Ltd., Victoria Station House, Victoria Street, London, S.W.1.—Booklet dealing with Monsanto "Silesters."

W. CANNING AND CO., Ltd., Great Hampton Street, Birmingham, 18.—New leaflet dealing with "Ohmax Insulated Plating Suspenders."

STURTEVANT ENGINEERING COMPANY, Ltd., Southern House, Cannon Street, London, E.C.4.—Publication No. 2303, describing Sturtevant products.

DYSON AND CO., ENFIELD (1919), Ltd., Southbury Works, Ponders End, Enfield, Middlesex.—Brochure describing the activities of the company.

THE GENERAL ELECTRIC COMPANY, Ltd., Magnet House, Kingsway, London, W.C.2.—Publication describing G.E.C. street lighting installations.

ALUMINIUM WIRE AND CABLE COMPANY, Ltd., 37, Thurloe Street, South Kensington, S.W.7.—Revised pages to the *Conductor Accessories Handbook*.

F. J. EDWARDS, Ltd., Edwards House, 359–361, Euston Road, London, N.W.1.—Catalogue No. WW 653, describing woodworking and veneering machinery.

THE DAVID BROWN CORPORATION (SALES), Ltd., Gear Works Division, Park Works, Huddersfield.—Publication giving full details of Radicon worm reducers.

AUTOMATIC TELEPHONE AND ELECTRIC COMPANY, Ltd., Strowger House, Arundel Street, London, W.C.2.—Publication R.E.B.204, "Radio Transmission Equipment."

NORMAND ELECTRICAL COMPANY, Ltd., North Street, Clapham Common, London, S.W.4.—Folder No. 531, which gives details of the complete range of Neco geared motors.

NORTHEY ROTARY COMPRESSORS, Ltd., 200–202, Alder Road, Parkstone, Dorset.—Leaflet CU.488, showing the design features of a Northey oil-free compressor or vacuum pump.

THE TELEGRAPH CONSTRUCTION AND MAINTENANCE COMPANY, Ltd., 22, Old Broad Street, London, E.C.2.—Booklet entitled "Aluminium Power Cables for the Transmission and Distribution of Electric Power."

THE WESTERN WIRE COMPANY, Ltd., 17, Central Chambers, Ealing Broadway, London, W.5.—Leaflet entitled "How One Man Can Move Half a Ton," giving full details and prices of the "MR Wheelabout" loader.

TURNERS ASBESTOS CEMENT COMPANY, Ltd., Trafford Park, Manchester, 17.—Three new data leaflets, "Ebony Grade Electrical Insulating Boards," "Natural Grade Asbestos Arc and Heat-Resisting Boards," "Synthetic Resin Bonded Asbestos Paper Sheets."

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on, or before, the morning of the Monday, of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BRITISH INSTITUTION OF RADIO ENGINEERS

Thurs., Dec. 3rd.—N.W. SECTION : College of Technology, Manchester, "The Monitoring of High-Speed Waveforms Using a Sampling Technique," J. G. MacQueen, 7 p.m.——MERSEYSIDE SECTION : Electricity Service Centre, Whitechapel, Liverpool, 1, Discussion on "Education in the Radio and Electronics Industry," 7 p.m.

CHEMICAL SOCIETY

Thurs., Dec. 3rd.—Burlington House, Piccadilly, London, W.1, Meeting for the Reading of Original Papers, 7.30 p.m.

INCORPORATED PLANT ENGINEERS

Mon., Nov. 30th.—W. AND E. YORKS BRANCH : The University, Leeds, "Some Recent Applications of Electronics in Industry," R. H. Wheat, 7.30 p.m.

Tues., Dec. 1st.—LONDON BRANCH : Royal Society of Arts, John Adam Street, Adelphi, Strand, W.C.2, "The Financial Implication of Plant Installation," H. L. Layton, 7 p.m.——EDINBURGH BRANCH : 25, Charlotte Square, Edinburgh, "Maintenance Painting," T. A. Banfield, 7 p.m.

Thurs., Dec. 3rd.—PETERBOROUGH BRANCH : Eastern Gas Board's Demonstration Theatre, Church Street, Peterborough, Discussion on "Plant Engineering," led by A. P. Brockbank, 7.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Wed., Dec. 2nd.—LONDON BRANCH : Waldorf Hotel, W.C.2, "Bell Founding," H. M. Howard, 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Wed., Dec. 2nd.—JUNIOR LECTURE : Technical College, East Ham, "The Influence of Arc Welding on Modern Engineering Design," K. K. Doherty, 7 p.m.

Thurs., Dec. 3rd.—KINGSTON UPON HULL AND E. MIDLANDS SECTION : Municipal Technical College, Kingston upon Hull, "Stress Analysis Using Photo-Elastic Method," J. Ward, 7.30 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Dec. 1st.—ROAD MEETING : Great George Street, Westminster, London, S.W.1, "Design and Construction of a High-Speed Test Track for Motor Vehicles," Ralph Freeman and J. A. Neill, 5.30 p.m.

Tues., Dec. 8th.—STRUCTURAL AND BUILDING MEETING : Great George Street, Westminster, London, S.W.1, "A Moment Distribution Method for the Analysis and Design of Structures by the Plastic Theory," M. R. Horne, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., Nov. 30th.—RADIO SECTION : Savoy Place, London, W.C.2, Section Soirée, 6.30 p.m.——S. MIDLAND CENTRE : Town Hall, Birmingham, Faraday Lecture, O. W. Humphreys.

Tues., Dec. 1st.—MEASUREMENTS SECTION : Savoy Place, London, W.C.2, Discussion on "The Influence of Legislation on the Costs of Metering," opened by S. Howarth, 5.30 p.m.——S.E. SCOTLAND SUB-CENTRE : Carlton Hotel, North Bridge, Edinburgh, "Special Effects for Television Studio Production," A. M. Spooner and T. Worswick, 7 p.m.

Wed., Dec. 2nd.—RADIO SECTION : Savoy Place, London, W.C.2, "Telegraph Codes and Code Converters," T. Hayton, C. J. Hughes and R. L. Saunders ; "Code Converters for the Interconnection of Morse and Teleprinter Systems," R. O. Carter and L. J. Wheeler, 5.30 p.m.——S.W. SCOTLAND SUB-CENTRE : Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Special Effects for Television Studio Productions," A. M. Spooner and T. Worswick, 7 p.m.——TEES-SIDE SUB-CENTRE : Cleveland Scientific and Technical Institute, Corporation Road, Middlesbrough, "Electrical Equipment of a Blooming Mill," G. G. Nicholson, 6.30 p.m.

Thurs., Dec. 3rd.—ORDINARY MEETING : Savoy Place, London, W.C.2, "Technical Arrangements for the Sound and Television Broadcasts of the Coronation Ceremonies on June 2, 1953," W. S. Procter, M. J. L. Pulling and F. Williams, 5.30 p.m.

INSTITUTION OF ENGINEERING INSPECTION

Tues., Dec. 1st.—COVENTRY BRANCH : Room A5, Technical College, Coventry, "Modern Developments of Mining Machinery," H. Entwistle and D. Creeth, 7.30 p.m.——S.W. BRANCH : Grand Hotel, Broad Street, Bristol, "Engineers at War (Part I), Bridging and Communications," W. H. Hooper, 7.30 p.m.

Wed., Dec. 2nd.—BIRMINGHAM BRANCH : Room 3, Chamber of Commerce, New Street, Birmingham, "Metallurgical Control of Drop Forgings," K. J. Abbott, 7.30 p.m.

Thurs., Dec. 3rd.—LONDON BRANCH : Royal Society of Arts, John Adam Street, Adelphi, W.C.2, "The Work of the Printing, Packaging and Allied Trades Research Association," G. Macdougall, 6 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., Dec. 1st.—39, Elmbank Crescent, Glasgow, "A Century of Coaster Design and Operation," J. C. Robertson and H. H. Hagan, 6.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Nov. 27th.—GENERAL MEETING : Storey's Gate, St. James's Park, London, S.W.1, "Fuel Systems and Controls for Marine Gas Turbines," R. F. Darling ; "Main Propulsion Gas Turbine Set for the Oil Tanker 'Auris,'" B. E. G. Forsling, 5.30 p.m.

Wed., Dec. 2nd.—APPLIED MECHANICS GROUP DISCUSSION : Storey's Gate, St. James's Park, London, S.W.1, "Materials for Pipelines in the Process Industries and Their Fabrication," 6.45 p.m.

Thurs., Dec. 3rd.—WESTERN BRANCH : Grand Hotel, Broad Street, Bristol, "An Experimental Single-Stage, Air-Cooled Gas Turbine," J. Reeman and R. W. A. Buswell, 7 p.m.

Fri., Dec. 4th.—GENERAL MEETING : Storey's Gate, St. James's Park, London, S.W.1, "Comparative High-Temperature Properties of British and American Steels," W. E. Bardgett and C. L. Clark, "A Critical Examination of Procedures Used in Britain and the United States to Determine Creep Stresses for the Design of Power Plant for Long life at High Temperatures," R. W. Bailey, 5.30 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Tues., Dec. 1st.—PETERBOROUGH SUB-SECTION : Dujon Ballroom The Market Place, Peterborough, "Jig and Tool Design," G. T. Sprayson, 7.30 p.m.

Wed., Dec. 2nd.—GLOUCESTER AND DISTRICT SUB-SECTION : Belle Vue Hotel, Cheltenham, "The Protection of Metal Components Against Atmospheric Corrosion," N. R. Laban, 7.15 p.m.——HALIFAX SECTION : White Swan Hotel, Halifax, "Some Interesting Set-Ups on Modern Machine Tools," R. C. Fenton, 7.15 p.m.——WOLVERHAMPTON SECTION : Technical College, Wolverhampton, "Human Relations in Industry," T. U. Matthew, 7.15 p.m.

Thurs., Dec. 3rd.—LONDON SECTION : The Old Ship Hotel, Assembly Rooms, Brighton, Sussex, "The Application of Scientific Administrative Methods to Engineering Production," C. Cooper, 7 p.m.——READING SECTION : Great Western Hotel, Reading, "Modern Cutting Tools and Machine Tool Design," C. H. A. Welsh, 7.30 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Tues., Dec. 1st.—NORTHERN COUNTIES BRANCH : Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, "Reconstruction of a Soaking Pit Building," H. C. Husband and K. H. Best, 6.30 p.m.

Wed., Dec. 2nd.—NORTHERN COUNTIES BRANCH : Neville Hall, Newcastle, "Reconstruction of a Soaking Pit Building," H. C. Husband and K. H. Best, 6.30 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Nov. 27th.—Townsend House, Greycoat Place, London, S.W.1, Annual General Meeting and Annual Meeting of Contributors to the Benevolent Fund, 7 p.m.

Wed., Dec. 2nd.—MIDLAND SECTION : James Watt Memorial Institute, Great Charles Street, Birmingham, "Gas Turbines," R. E. Wigg, 7 p.m.

Fri., Dec. 4th.—Townsend House, Greycoat Place, London, S.W.1, Film Evening, 7 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

To-day, Nov. 27th.—Engineers' Club, Albert Square, Manchester, "Fluid Couplings and the Application in Electric Motor and Diesel-Engine-Driven Equipment," E. C. Farrer, 6.45 p.m.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, Nov. 27th.—Mining Institute, Newcastle upon Tyne, "Experience During the Last Ten Years in the Design of Marine Boilers," R. L. J. Hayden, 6.15 p.m.

REINFORCED CONCRETE ASSOCIATION

Wed., Dec. 2nd.—Liverpool Engineering Society, 24, The Temple, Dale Street, Liverpool, "Recent Developments in Prestressed Concrete Construction," A. J. Harris, 6.30 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., Dec. 1st.—4, Hamilton Place, London, W.1, "Integral Construction," K. L. G. Legg, 7 p.m.